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Habitat Use and Population Status of Woodland Caribou in the Quesnel Highlands, British Columbia

by

Dale R. Seip

Wildlife Bulletin No. B-71
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SUMMARY

1. The purpose of this project was to determine the seasonal habitat requirements and population status of woodland caribou in the Quesnel Highlands, British Columbia.

2. Sixteen to 19 radio-collared caribou were monitored each year between 1984 and 1989 to determine movements, habitat use and population parameters. In addition, four wolves and five moose were monitored by radio-telemetry to determine predator-prey interactions of caribou, wolves and moose. Wolf control was implemented during the last 2 years of the study to evaluate the effect of wolf predation on caribou survival.

3. Caribou did not migrate between distinct seasonal ranges but moved widely throughout the year over annual home ranges that ranged from 84 to 372 km^2.

4. In early winter (November-December), about 60% of caribou locations were in high elevation, subalpine fir forests, about 20% were in mid-elevation spruce/subalpine fir forests and 20% were in low elevation cedar/hemlock forests. When habitat use of caribou was compared to habitat availablity in early winter, mature (>80 years) balsam (subalpine fir) and balsam-spruce forest cover types were selected (use > availability) and immature forest types were avoided (use < availability).

5. In late winter (January-April), about 80% of caribou locations were in high elevation subalpine fir forests and open, subalpine parkland habitats. When habitat use and availability were compared, alpine and mature balsam-spruce forest cover types were selected (use > availability) and mature spruce, cedar, hemlock and immature forest cover types were avoided (use < availability.

6. In May, about 25% of caribou locations were in low elevation habitats, where caribou had access to new plant growth, but most locations were in subalpine habitats. Throughout the summer, over 60% of caribou locations were in alpine and subalpine forest types.

7. In winter, caribou fed primarily on arboreal lichens and conifer browse. In summer, caribou fed on a variety of shrubs, forbs, graminoids and lichens. In early winter, caribou in the subalpine fed primarily on lichens and conifer browse whereas caribou at low elevations also fed on shrubs.

8. Adult caribou had an annual mortality rate of 29%. Causes of adult mortality (for the 18 cases when the cause could be determined) were wolf predation (55%), bear predation (15%), accidents (18%) and malnutrition (12%).

9. Adult female caribou had a pregnancy rate of 95%. Only 50% of adult females had surviving calves by late June, indicating a high mortality of calves at or soon after calving. After the calving period, calf survival was related to wolf abundance. When wolves were present and uncontrolled in the study area, only 1 of 40 (2.5%) radio-collared, adult female had a calf survive to October. When wolves were absent from the study area or numbers were reduced by wolf control, 9 of 23 (39%) radio-collared, adult females had surviving calves in October.

10. High adult mortality rate and low calf survival during the study period suggested a population decline of about 25% each year. Census data also indicated the caribou population declined about 25% annually, from 220 in 1986 to 94 in 1989.

11. Throughout the year, moose and wolves used similar habitats and moose were the primary prey of wolves. In winter, wolves and moose were located in valley bottoms and were spatially separated from caribou. In summer; wolves, moose and caribou often occupied the same subalpine habitats and high wolf predation on caribou occurred at that time.

12. Major declines in caribou numbers at Quesnel Lake and other areas of central British Columbia are attributed to increases in the number of moose in the 1920's. The presence of moose supports increased wolf numbers and results in a high predation rate on caribou.

13. Management recommendations to protect caribou include:

i) Wolf control, ideally combined with an intensive moose harvest, is probably necessary to allow the caribou population to increase and may be necessary to prevent further declines.

ii) Protection of important caribou habitats from logging. Upper elevation, mature, subalpine fir forests (alpine, mature balsam and balsam-spruce forest cover types) are the most important habitats to protect. mid-elevation spruce-balsam and low elevation cedar/hemlock forests are used by caribou, especially in early winter, so some of these areas also merit protection. Corridors of mid-elevation and valley-bottom forests linking areas of important subalpine habitat could be used to provide both early winter range and movement corridors.

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INTRODUCTION

Woodland caribou *(Rangifer tarandus caribou)* populations declined throughout British Columbia during the 1900's (Bergerud 1974, 1978). Although accurate census data are not available, subjective estimates in "The Report of the Provincial Warden" indicate that caribou in the Quesnel/Williams Lake area declined from "large herds" in 1880 to "plentiful" in 1929 to "scarce" by 1938 (cited in Stevenson and Hatler 1985). Caribou populations continued to decline in southeastern British Columbia throughout the mid-1900's (Edwards 1954) and disappeared from large parts of their historic range (Stevenson and Hatler 1985).

Those declines were often attributed to habitat destruction by logging and fires (Edwards 1954; Bloomfield 1980). In southeastern British Columbia, caribou feed primarily on arboreal lichens in winter and lichens are most abundant in old-growth forests. Destruction of those forests by fire or logging reduces the primary food source of the caribou. Sufficient amounts of important caribou habitat must be protected from logging if caribou populations are to be maintained. Young and Beets (1980) proposed logging guidelines to protect caribou habitat in the Quesnel Highlands based on the limited information available at that time. However, additional information on caribou habitat use was needed to refine habitat protection practices.

Bergerud (1974, 1978) suggested that predation by wolves *(Canis lupus)* was a major cause of decreased caribou numbers in British Columbia. Bergerud and Elliot (1986) proposed that the colonization of British Columbia by moose *(Alces alces)* in the early 1900's supported increased wolf populations and led to increased predation on caribou. Overhunting was also implicated as a cause of caribou declines (Bergerud 1978; Bloomfield 1980). The relative importance of overhunting, predation and food resources as limiting factors for the caribou was unknown. Therefore, additional information on limiting factors and population status of the caribou was required.

The Quesnel Highlands caribou project was initiated in 1984 as a co-operative venture between the B.C. Ministry of Environment, Lands and Parks and the forest industry to resolve these caribou/forest management issues (Hebert and Seip 1984). The objectives of this project were:

1. to determine the seasonal pattern of habitat use by caribou in the Quesnel Highlands to facilitate habitat protection and forest management decisions, and

2. to determine population status and important limiting factors of the caribou.

Funding for this project was provided by the British Columbia Ministry of Environment, Lands and Parks (Cariboo Region), Weldwood of Canada Ltd., Jacobson Brothers Forest Products Ltd., Starline Cedar Mills Ltd., Natural Sciences and Engineering Research Council (post-doctoral fellowship) and the Science Council of B.C.

Daryll Hebert initiated and assisted with all aspects of the project. Jim Young, Ken Prest and Rob Woods provided major assistance with fieldwork and data collection. Additional field assistance was provided by numerous individuals, including Francois Messier, Tom Smith and Shane Swanson. Aircraft pilots included Tom Arduini, Al Peltier, Gideon Schutze and "Slim" Sherk.

STUDY AREA

The study area comprised about 2,300 km^2 and was situated in the Quesnel Lake area of central British Columbia (Fig. 1). The area is primarily in the Quesnel Highlands physiographic region, although the northeastern section extends into the Cariboo Mountains (Holland 1976). The Quesnel Highlands consist of moderately sloping plateaus and rounded mountains (Fig. 2), rising from 728 m at Quesnel Lake and rarely exceeding 2200 m in elevation. The area has high annual precipitation (844-1123 mm; MOF 1987) with winter snow depths exceeding two metres in the mountains (Ministry of Environment 1985).

The Interior Cedar Hemlock biogeoclimatic zone, both the Quesnel Lake variant (ICHh1) and the Cariboo Lake variant (ICHh2), occurs at lower elevations up to about 1250 m (MOF 1987). The Engelmann Spruce Subalpine Fir zone (ESSF) occurs above the ICH zone up to about 1800 m. The ESSF zone is divided into a lower elevation variant (ESSFh1) that occurs below 1500 m and an upper elevation variant (ESSFh2) that occurs above 1500 m. Alpine tundra (AT) is present above the ESSF zone.

The lower elevation ICH forests are dominated by western hemlock *(Tsuga heterophylla)* and western redcedar *(Thuja plicata)*, with Douglas-fir *(Pseudotuga menziesii)*, Engelmann spruce *(Picea engelmannii)* and lodgepole pine *(Pinus contorta)* common on some sites. The understory is quite open with a ground cover of mosses, small ferns and forbs, and a sparse shrub layer, especially falsebox *(Paxistima myrsinites)*. The lower elevation variant of the ESSF zone is dominated by Engelmann spruce with some subalpine fir *(Abies lasiocarpa)*, whereas the upper variant is dominated by subalpine fir. At treeline, the upper band of the ESSF zone often consists of an open parkland forest type. The understory of the ESSF zone often contains a dense shrub layer of white rhododendron *(Rhododendron albiflorum)*.

Some of the lower elevation forests, especially in the Spanish Lake and Cariboo Lake area, were logged during the previous 15 years and had road access. However most of the area was inaccessible wilderness during the study.

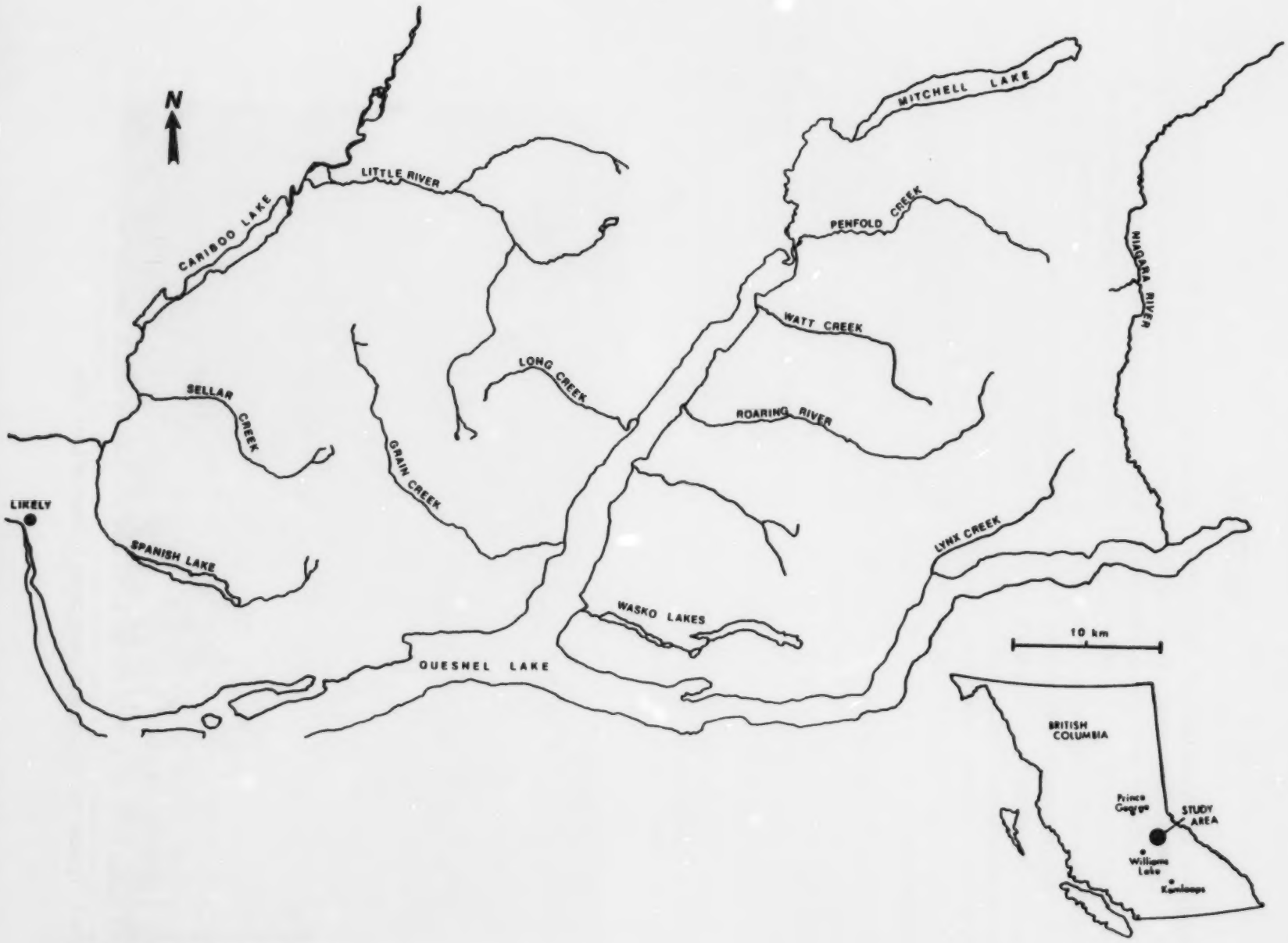

Figure 1. Map of the study area.

METHODS

The study was conducted between March 1984 and March 1989. Each year, from 16 to 19 radio-collared, adult, female caribou were monitored. Caribou were captured in March when they were at high elevations in open habitat types. Most caribou were captured by net gunning from a helicopter although several were captured at the start of the project by darting with M-99 (Etorphine hydrochloride). Additional caribou were captured each March to replace animals that had died during the previous year.

Netted caribou were tranquillized with an injection of 0.75 -1.0 cc of Rompun (Xylazine hydrochloride) and restrained with leg hobbles. The animals were fitted with radio collars that had motion-sensitive mortality sensors. Coloured eartags were attached to aid visual identification. A blood sample was collected from the front leg vein of each individual, centrifuged and plasma collected and frozen for storage. Plasma progesterone concentration was determined by radioimmunoassay (B.C. Biomedical Lab., Burnaby) to determine if the animals were pregnant at time of capture (Rehbinder *et al.* 1981).

Four wolves were trapped and radio-collared in July 1984. The wolves were captured in leg-hold traps set along logging roads.

The radio-collared animals were located two to four times each month by telemetry from an airplane. Location, habitat type and elevation

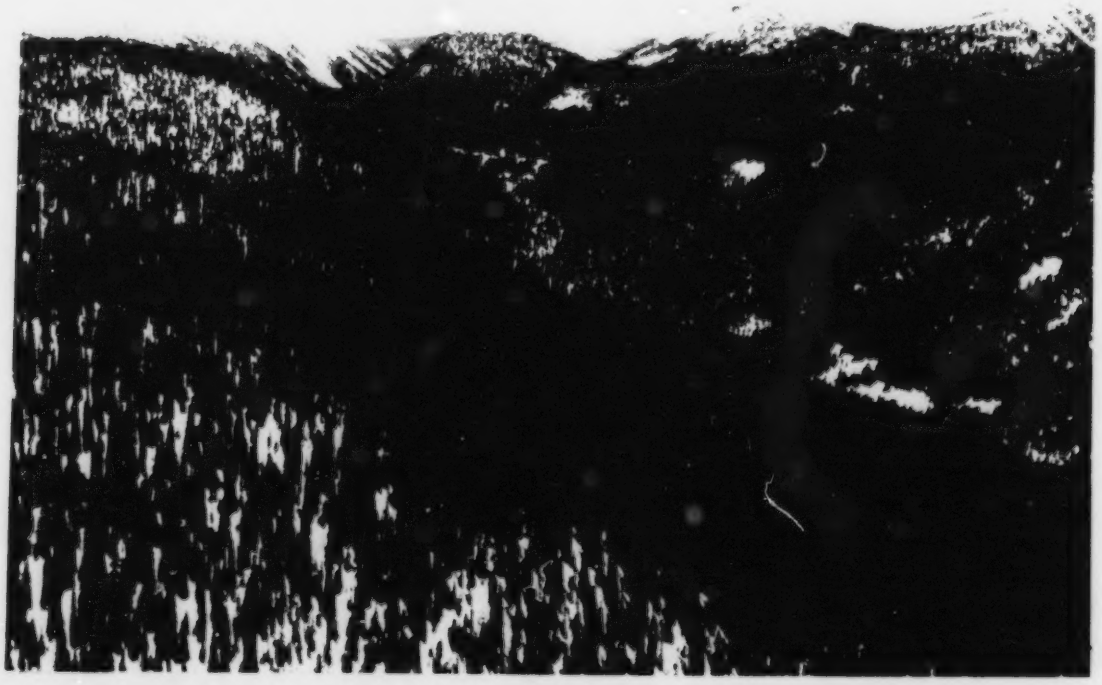

Figure 2. Typical topography and forest cover in Quesnel Lake area.

were recorded for each location. Location coordinates were coded for computer plotting and analysis of home ranges. Home ranges were calculated by the minimum convex polygon method using the HOME program (Harestad 1981). Use of forest cover types was determined by overlaying a plot of caribou locations onto MOF forest cover maps. Availability of forest cover types was determined by overlaying a plot of 300 random points onto forest cover maps. Forest cover types were separated into mature (>80 years) and immature (<80 years) age classes. Differences between use and availability were compared using the Bonferroni Z-statistic (Neu *et al.* 1974).

When a motion-sensitive radiocollar indicated that a caribou had died, the animal was located and necropsied to determine the cause of death. Position of the carcass, predator sign and bone marrow fat content were used to determine the cause of mortality.

Calf counts were conducted from a helicopter in late June, August and October each year. Each radio-collared caribou was observed to determine if it was accompanied by a calf. The proportion of all cows seen (collared and uncollared) that had calves was also recorded. Calf/cow ratios were compared using 2 X 2 contingency tables (Sokal and Rohlf 1973).

The population was censused from a helicopter each year in March when most of the caribou were in open, subalpine habitat. The entire study area was searched by flying along treeline and open meadows in each watershed looking for tracks. When tracks were located, the area was searched until the caribou were found. Censuses were conducted as soon as possible after a new snowfall because extensive areas soon became covered in tracks, making it difficult to locate the caribou. Number of adults, number of calves and number of collared caribou in the group were recorded. The proportion of collared animals known to be in the study area that were seen during the census was used to correct the total count for animals that were missed. The census was directed by the helicopter pilot who did not have prior knowledge of where collared caribou were located, thereby preventing a biased search.

Caribou fecal samples were collected throughout the year and analysed for nitrogen content using the micro-Kjeldahl method (Dep. of Animal Science, Univ. of B.C., Vancouver). Food habits were determined by fecal fragment analysis of a composite sample of ten fecal pellet groups (Wildlife Habitat Lab., Wash. State Univ., Pullman). Four rumen samples from caribou that died were also analysed using the same technique as for fecal samples. Wolf scats were collected opportunistically throughout the year and analysed to determine diet based on the percentage of hair from different prey species. The percentage of prey hair in scats was corrected for the body size of prey species (Floyd *et al.* 1978).

In the winter of 1987, four adult female wolves were shot as part of a small scale wolf control program on the east side of Quesnel Lake. In the winter of 1988, seven wolves were shot in the study area.

Data on moose movements on the west side of Quesnel Lake were determined from five radio-collared moose being monitored by the Ministry of Environment, Lands and Parks. Moose were located weekly during the winter and every two weeks in summer. No moose were radio-collared on the east side of Quesnel Lake but important moose winter ranges were determined during annual moose census flights.

RESULTS

SEASONAL MOVEMENTS

Although the caribou moved widely during the year (Appendix A), there was no distinct seasonal migration pattern between summer and winter ranges. Similar areas were used in winter and summer (Figs. 3,4,5). Annual home ranges (minimum convex polygon) of caribou averaged 247 km^2 (SD = 72, n=50), ranging from 84 to 372 km^2. Caribou often used areas in one year that were not included in their home range the previous year. The overlap in annual home ranges from one year to the next averaged 50% (SD = 29%) and ranged from 0 to 100%, that is, for some caribou, there was no overlap between the home range used one year and the home range the next year. Therefore, the longer a caribou was monitored, the greater the total area it used (Table 1).

Table 1. Total area used (km^2) by radio-collared caribou.

	Total area used (km^2)			
Years of Monitoring	Mean	SD	Range	N
1	251	56	141-363	18
2	349	80	226-499	14
3	501	108	394-752	11
4	526	98	422-646	7

SEASONAL HABITAT USE

Early winter: -- In November and December, about half of the caribou locations were above 1600 m in the upper variant of the ESSF biogeoclimatic zone in mature balsam (subalpine fir), balsam-spruce and alpine forest cover types (Figs. 6,7,8,9). About 30% of the caribou locations were between 1300 and 1600 m in the lower variant of the ESSF biogeoclimatic zone in spruce and spruce-balsam forest cover types. The remaining 20% of the radio-collared caribou locations were in low elevation, cedar/hemlock forest types in the ICH zone. Most of the low elevation habitats used by caribou in early winter were along the shores of Quesnel Lake, especially at the mouth of Grain Creek, Lynx Creek and Watt Creek (Fig. 3).

About 80% of the early winter locations were in forested habitats, 20% in parkland habitats and few or none in open alpine and meadow habitats (Fig. 8).

Caribou used a wide variety of forest cover types in early winter (Fig. 9) but use differed from availability (x^2=98, 8 df, $p < .05$). Use of mature (>80 years) balsam and balsam-spruce types exceeded availability and use of immature (<80 years) types was less than availability ($p < .05$).

Use of cedar/hemlock forests in early winter ranged from 18-27% of the caribou locations in different years and appeared to be related more to individual variation among caribou than to year to year environmental variation. For the 14 caribou that were monitored for more than one early winter period, use of cedar/hemlock forests ranged from 0 to 67% of their November/December locations. Four of those 14 caribou were never located in cedar/hemlock stands during early winter whereas three had more than 50% of their early winter locations in cedar/hemlock. For the seven caribou that were monitored for four consecutive early winter periods, cedar/hemlock forests were not used by two of the caribou, were used in just one year by one caribou, were used in two years by two caribou and were used all four years by two of the caribou.

Winter: -- In January-February, caribou used primarily high elevation ESSF forests (ESSFh2 variant) and subalpine parkland habitats (Figs. 6,7,8). About 75% of locations were above 1600 m and less than 10% of locations were in low elevation cedar/hemlock forests. As winter progressed, caribou gradually moved to even higher elevations and used more open forest types. By March - April, most caribou locations were in subalpine parkland and subalpine meadow habitats. Almost 90% of the locations were above 1600 m. and there was almost no use of low elevation cedar/hemlock types until late April when some animals began to move down for early spring forage.

About 80% of the caribou locations were in alpine forest and mature balsam and balsam-spruce forest cover types (Fig. 10). Use of forest cover types was different from availability during the winter period (x^2=536, 8 df, $p < .05$). Use of alpine forest and mature balsam-spruce forest cover types was greater than availability ($p < .05$) and use of mature spruce, cedar, hemlock and immature forest cover types was less than availability ($p < .05$).

Caribou locations during the winter were widespread throughout the study area (Fig. 4) and areas of heavy use varied from year to year. In general, caribou selected areas of gentle topography such as plateaus, ridge tops and bowls and avoided steep, rugged terrain.

Figure 3. Early winter (Nov.-Dec.) locations of radio-collared caribou.

Figure 4. Late winter (Jan.-Apr.) locations of radio-collared caribou.

Figure 5. Summer (May-Oct.) locations of radio-collared caribou.

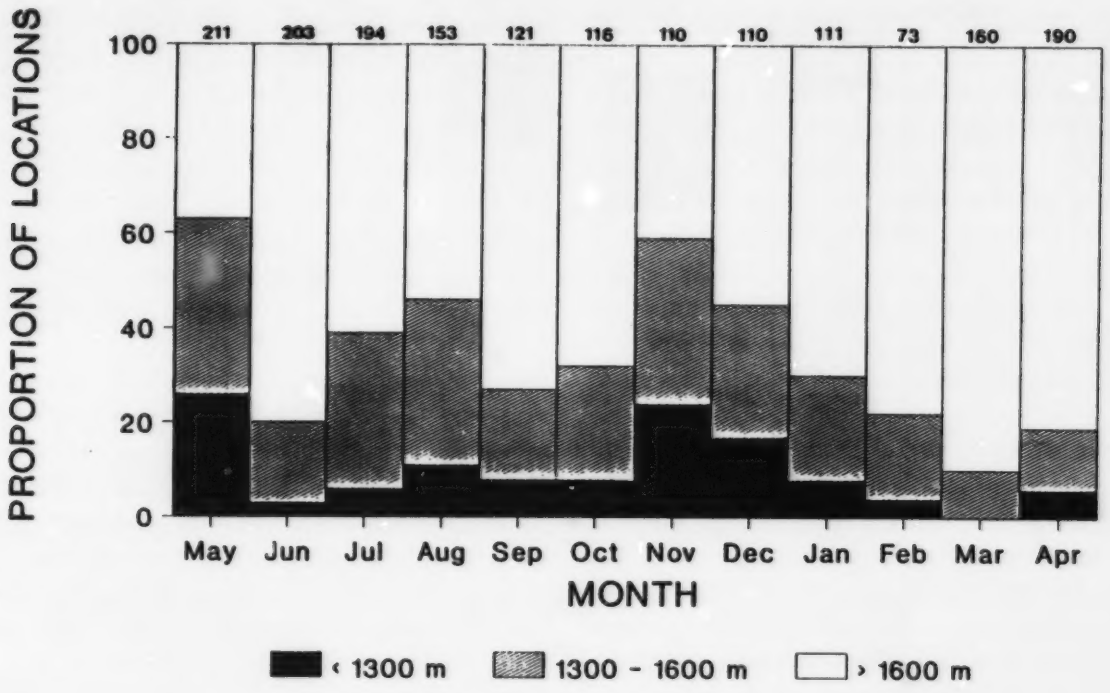

Figure 6. Proportion of radio-collared caribou locations at different elevations during different months. Sample size given above each bar.

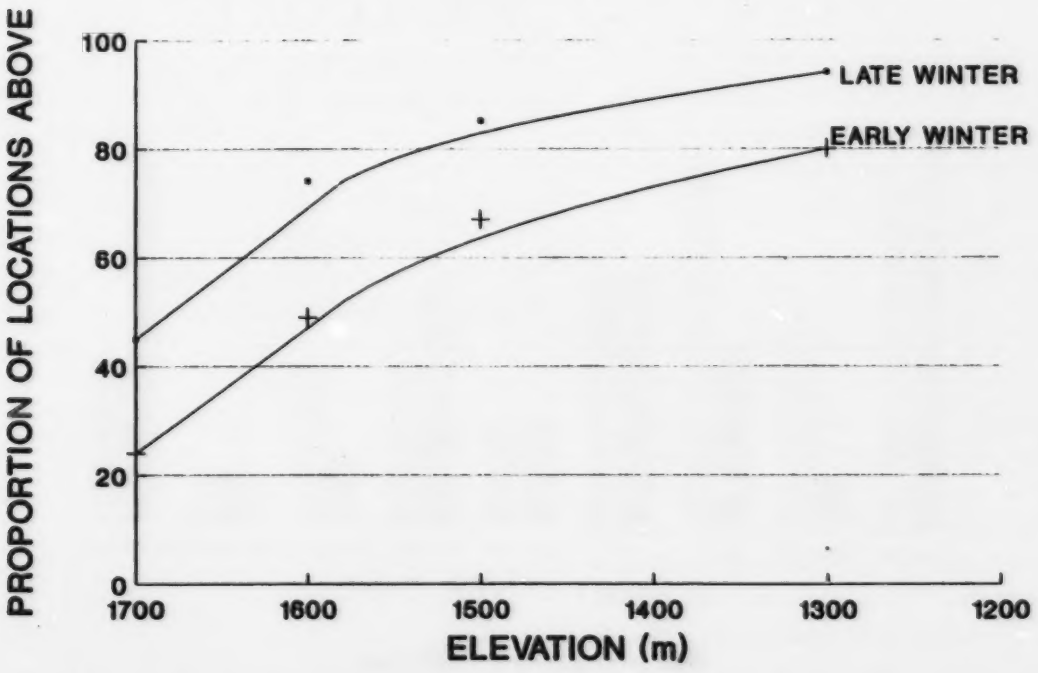

Figure 7. Cumulative proportion of caribou locations above different elevations in early and late winter (n=228 in early winter, 535 late winter).

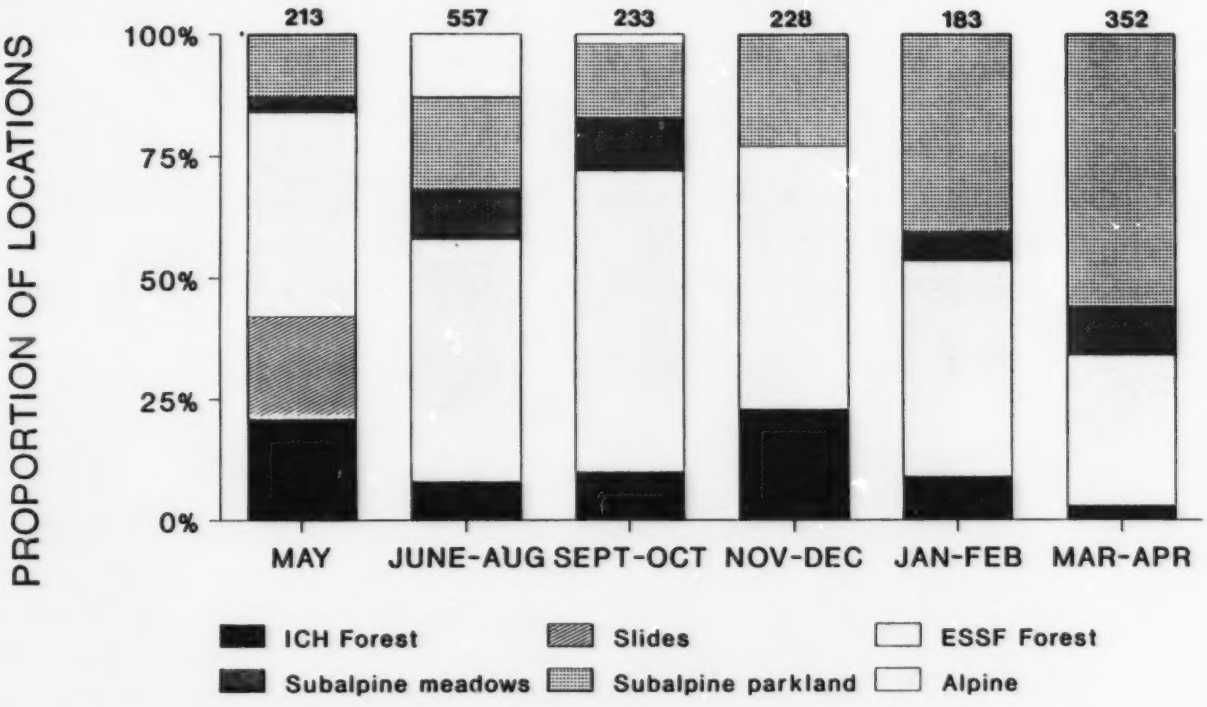

Figure 8. Proportion of radio-collared caribou locations in different habitat types during different seasons. Sample size given above each bar.

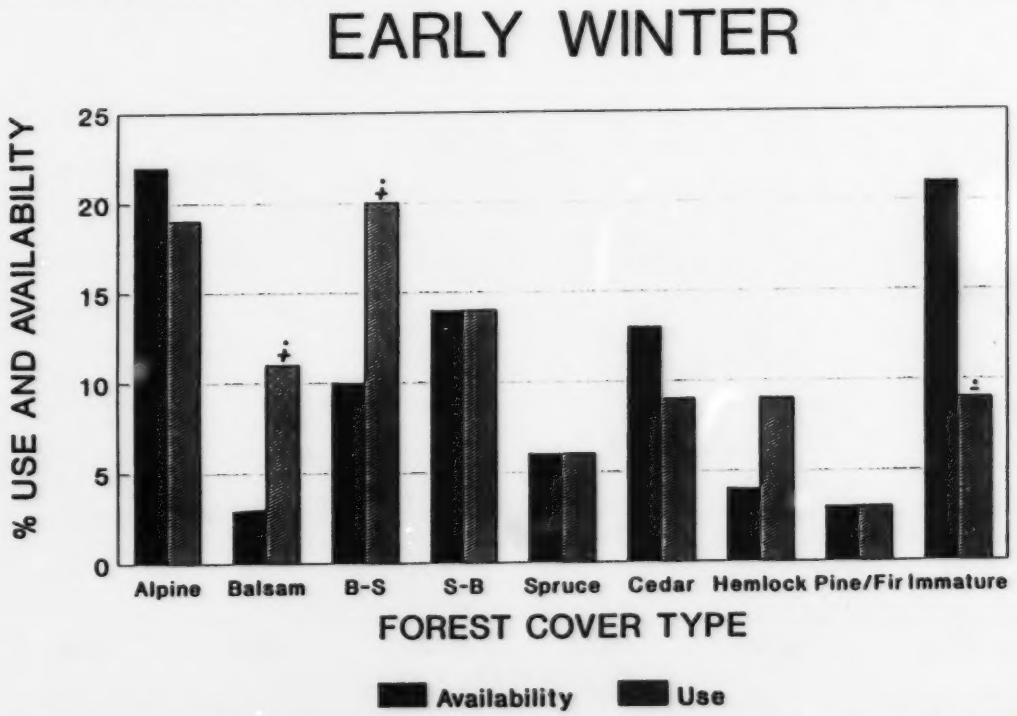

Figure 9. Caribou use (n=216) of forest cover types in early winter (Nov.-Dec.) compared to availability (+ indicates selection, - indicates avoidance, $p < .05$).

Spring: -- In May, most caribou moved to lower elevations (Fig 6). Most locations were in ESSF forests but at lower elevations than in winter (Fig 8). About 20% of locations were in cedar/hemlock forests and about 20% were on slides. Some limited ground tracking indicated that caribou using cedar/hemlock forests in spring appeared to select small forest openings such as seepage sites and roadsides for foraging.

Summer: -- Throughout the summer months, caribou were located primarily in high elevation ESSF forests, subalpine meadows, subalpine parkland and some open alpine areas (Figs. 6,8). Use of high elevation alpine areas was especially common for adult, female caribou during the calving period in June but as summer progressed, they increased use of mid and low elevations (Fig. 6).

During the summer months, most caribou locations were in alpine, balsam, balsam-spruce and spruce-balsam forest cover types (Fig. 11). Use of forest cover types was different from availability (x^2=555, 8 df, $p < .05$). Use of mature balsam and balsam-spruce types was greater than availability and use of immature forest cover types was less than availability ($p < .05$).

Caribou were widely distributed throughout the study area during summer (Fig 5). Areas of gentle topography such as plateaus and bowls were used by caribou whereas areas of steeper terrain were avoided.

FOOD HABITS AND DIET QUALITY

From January to April, fecal fragment analyses indicated that lichens constituted about 80% of the diet and conifer browse made up about 20% (Fig. 12). Rumen samples also indicated that lichens and conifer browse were the primary food items in winter, although they contained more conifer material than lichen (Fig 13). Fecal nitrogen concentrations in winter indicated that the protein content of winter forage was low (Fig 14).

In May, caribou that used low elevation forests and slides fed on shrubs, forbs and graminoids in addition to lichens and conifer browse. Caribou that used subalpine forests in May continued to feed primarily on lichens and conifers although they also consumed some mosses and shrubs indicating that ground forage was becoming available at that time. Caribou that used lower elevations had higher fecal nitrogen concentrations than caribou that remained in the subalpine ($t=1.82$, $df=18$, $p < .05$).

Throughout the summer months, caribou fed on a variety of shrubs, forbs and graminoids but lichens remained a significant component of the diet (Figs. 12,13). Fecal nitrogen concentrations indicated a high quality diet during the summer.

In October, November and December, lichens increased in importance in the diet whereas shrubs, forbs and graminoids decreased in importance. Caribou using cedar/hemlock forests in early winter consumed more shrubs, forbs and graminoids than did caribou in the subalpine. A decrease in fecal nitrogen concentrations indicated a decreasing protein intake during this period. There was no difference between fecal nitrogen concentrations for caribou in low elevation forests and caribou in the subalpine during early winter.

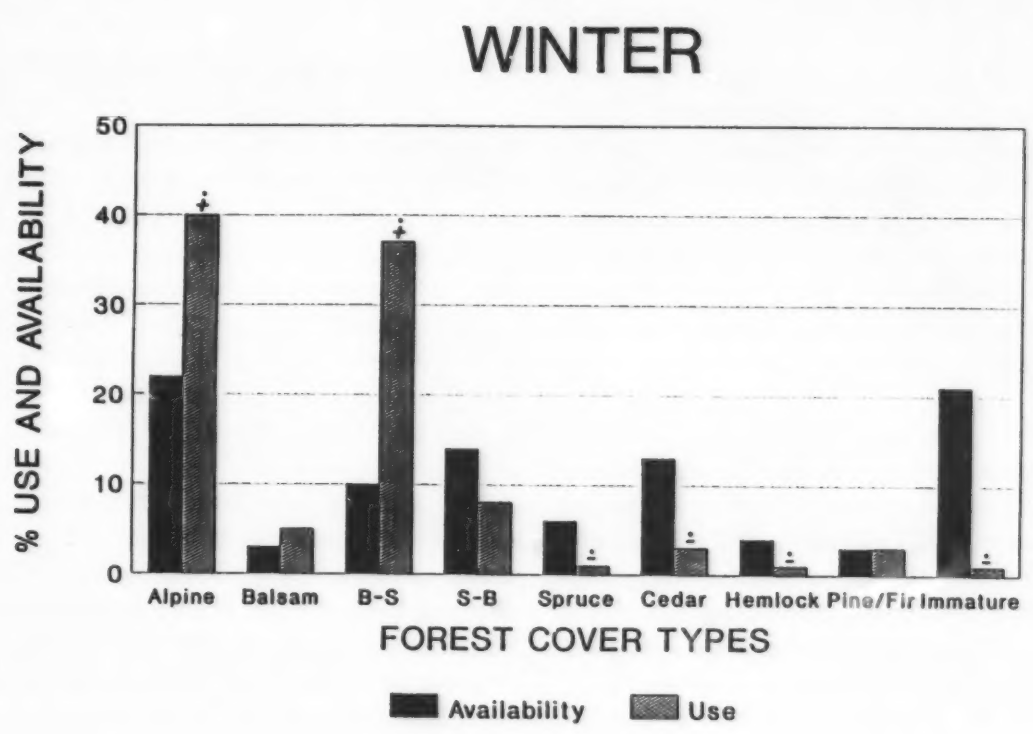

Figure 10. Caribou use (n=527) of forest cover types in late winter (Jan.-Apr.) compared to availability (+ indicates selection, - indicates avoidance, $p < .05$).

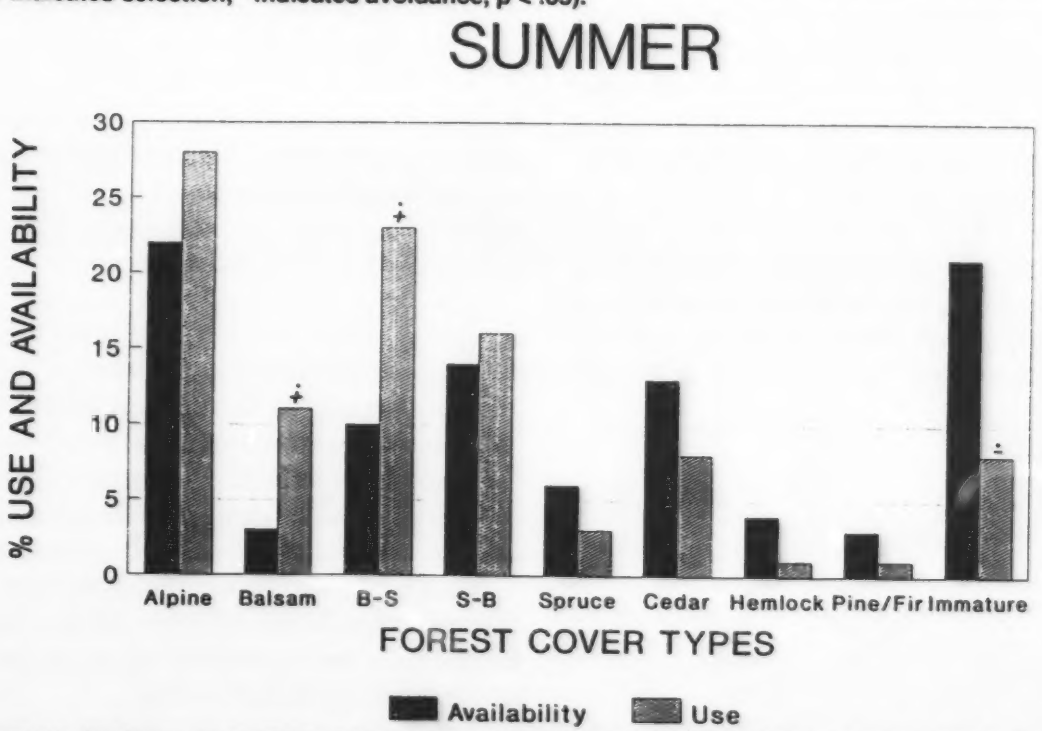

Figure 11. Caribou use (n=957) of forest cover types in summer (May-October) compared to availability (+ indicates selection, - indicates avoidance, $p < .05$).

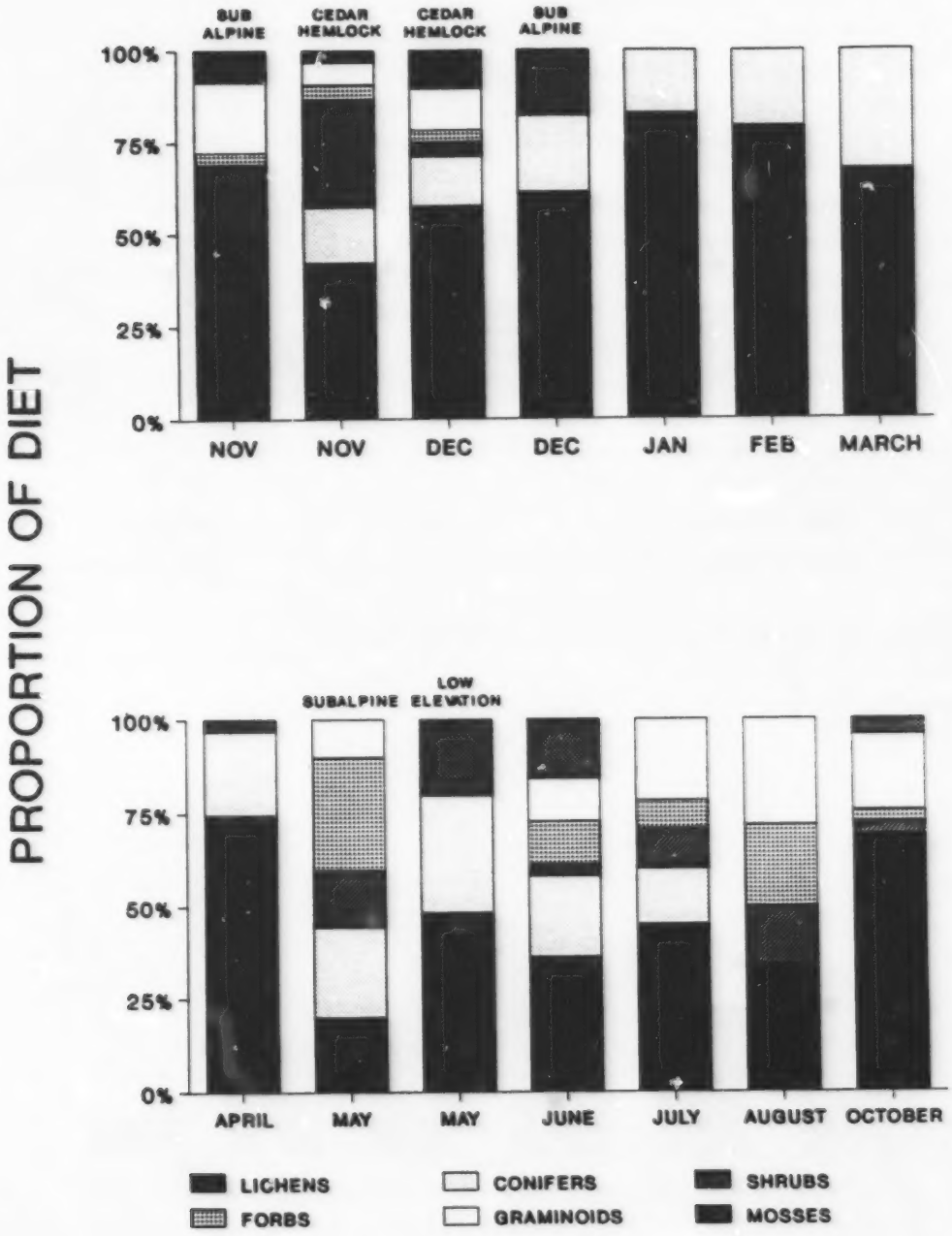

Figure 12. Seasonal food habits of caribou based on fecal fragment analysis (composite of ten pellet groups).

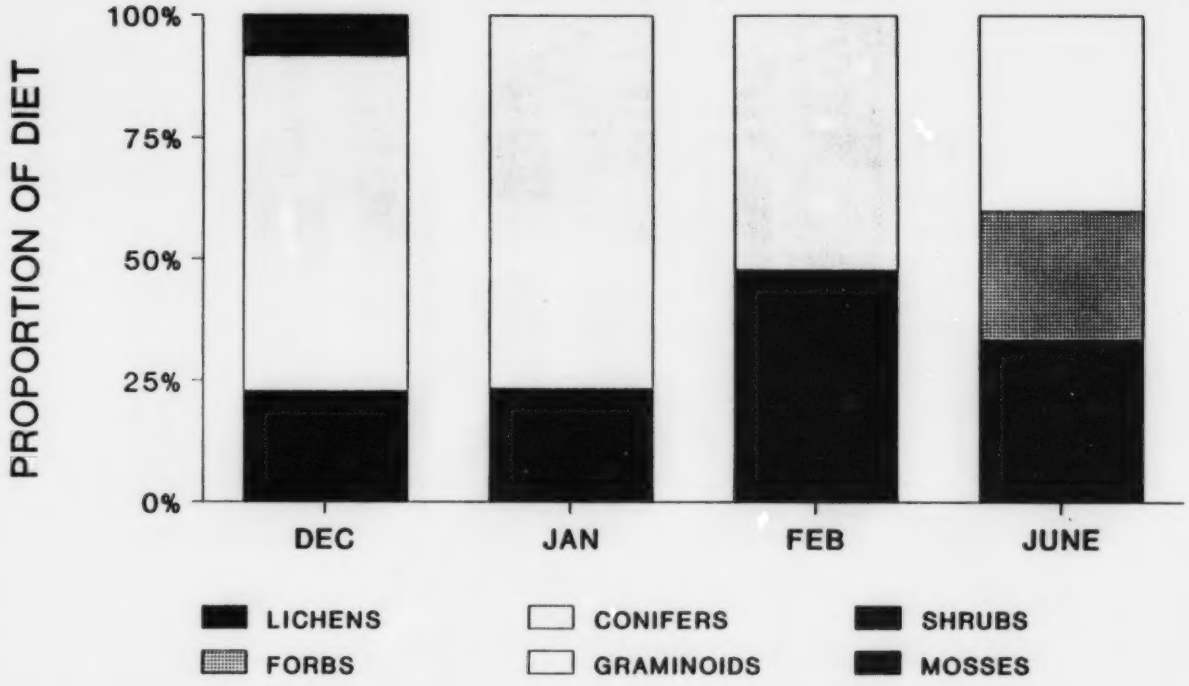

Figure 13. Seasonal food habits of caribou based on rumen analysis (n=4).

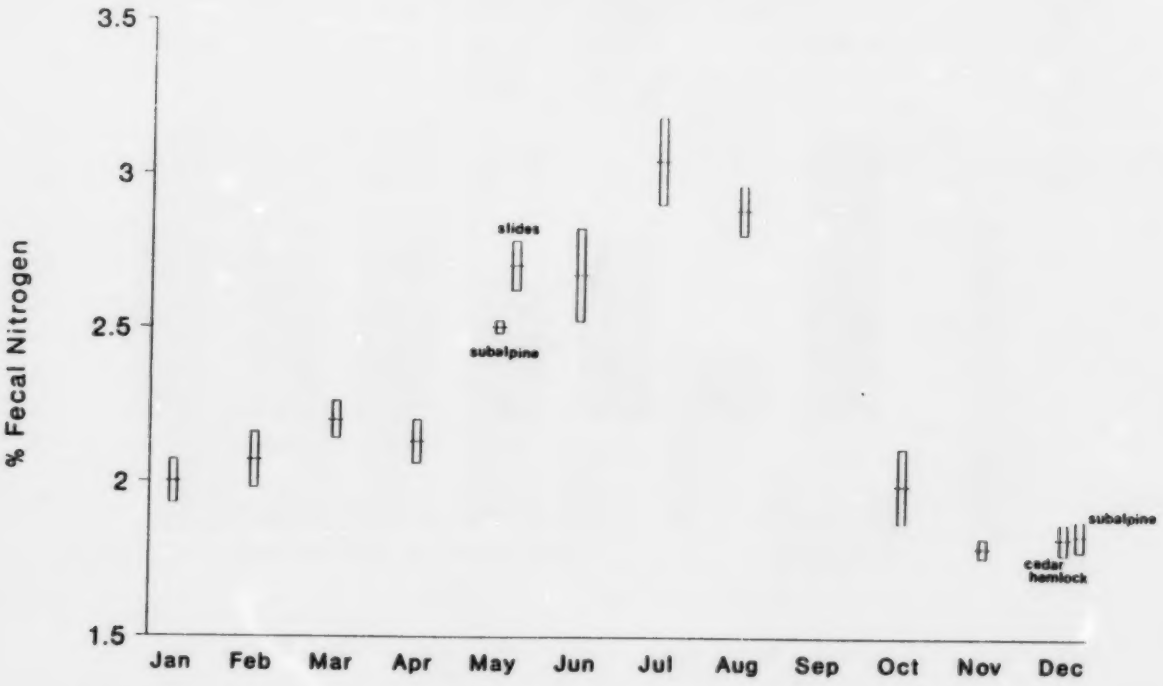

Figure 14. Seasonal pattern of caribou fecal nitrogen level (X + SE, n=10).

POPULATION PARAMETERS

Adult mortality: -- The annual adult mortality rate was 29% + 5 (SD), based on 23 radio-collared caribou deaths during 79 caribou-years of monitoring. For the 18 cases where it was possible to determine the cause of death with reasonable confidence, 10 (55%) were due to wolf predation, 3 (17%) due to bear predation *(Ursus arctos or U. americana)*, 3 (17%) were accidents and 2 (11%) malnutrition (Fig. 15). Deaths attributed to malnutrition were based on depeleted bone marrow.

Most caribou mortalities occurred in spring, summer and early winter. Deaths due to wolf predation occurred during summer and early winter whereas bear predation occurred during spring and early summer. The two deaths due to malnutrition occurred during summer and the three accidents occurred in fall and winter. Accidental deaths included an avalanche, a fall into a ravine and a dislocated hip leading to starvation.

The average elevation of caribou mortalities (1287 m, SD = 365), especially those due to bear and wolf predation (1265 m, SD = 400), was lower than the average elevation of radio-collared caribou locations (Fig. 6) which suggests that caribou were more vulnerable to predators when they were at lower elevations.

Calf Production and Survival: -- Plasma progesterone concentrations indicated that 20/21 (95%) adult (2+ years) females were pregnant at time of capture. Plasma progesterone concentrations for pregnant animals ranged from 3.5 to 11.3 ng/ml compared to 0.1 ng/ml for the non-pregnant animal. Also, all four adult, female caribou that died and were necropsied during the winter months were pregnant. The one 21 month-old female that was captured was not pregnant, based on plasma progesterone concentration (0.2 ng/ml).

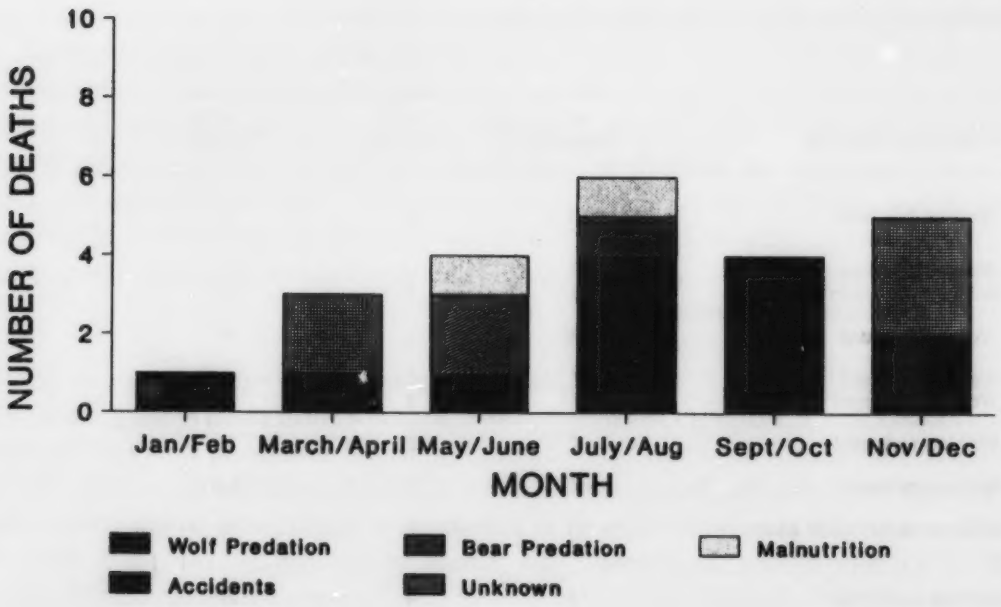

Figure 15. Timing and causes of mortality for radio-collared, adult, female caribou.

In late June, following the calving period, only 50% (36/72) of the radio-collared, adult, female caribou were accompanied by surviving calves, indicating that about half of the newborn calves died at birth or during the first two weeks after birth. Only 38% (65/170) of all cows seen during June calf counts had surviving calves. The low calf counts for both collared and uncollared cows indicate that the low calf counts of collared cows were not caused by capture stress.

In 1984, when wolves were present on both sides of Quesnel Lake, the proportion of cows with calves decreased rapidly during the summer months and by October, no radio-collared cows and very few (2/36) uncollared cows had surviving calves (Figs. 16, 17; Table 2). The following March, there were 8.3 calves/100 adults in the population (Table 3).

In March of 1985, the radio-collared wolves from the west side of the North Arm of Quesnel Lake crossed the ice and remained on the east side of the North Arm the following summer. Weekly surveys of roads on the west side of Quesnel Lake to collect wolf scats indicated that wolves were rare or absent during the summer of 1985. The absence of wolves corresponded to high caribou calf survival compared to the east side of the lake where wolves were present (Fig. 16). The following March, there were 23 calves/100 adults in the area where wolves were absent compared to none on the side of the lake where wolves were present the previous summer.

In 1986, wolves were again present on both sides of Quesnel Lake and calf survival declined rapidly during the summer and by March, there were only 10 calves/100 adults. In March of 1987, four adult, female wolves were shot on the east side of Quesnel Lake as part of a small scale wolf control program to evaluate the effect of wolf predation on caribou survival. In addition, a radio-collared wolf and at least one associated wolf moved out of the area to

Table 2. Percentage of radio-collared, female caribou with calves in October.

Year	Wolf Abundance	Number of Females	Number with Calves	Percent with Calves
1984	Wolves present	11	0	0
1985	Wolves present	8	0	0
1985	Wolves naturally absent	9	5	56
1986	Wolves present	14	1	7
1987	Wolves present	7	0	o
1987	Wolves reduced	7	2	29
1988	Wolves reduced	7	2	29
Total	Wolves present	40	1	2.5
Total	Wolves reduced or absent	23	9	39
Total	wolves reduced	14	4	29

Table 3. Number of calves/100 adults in March.

Year	Wolf Abundance	Number of Adults	Number of Calves	Calves/ 100 Adults
1985	Wolves present	109	9	8.3
1986	Wolves present	65	0	0.0
1986	Wolves naturally absent	96	22	23.0
1987	Wolves present	141	14	9.9
1988	Wolves present	49	2	4.0
1988	Wolves reduced	35	5	14.0
1989	Wolves reduced	94	6	6.0
Total	Wolves present	364	25	6.9
Total	Wolves reduced or naturally absent	225	33	14.7
Total	Wolves reduced	129	11	8.5

the east side of Wells Gray Park. That reduction in wolves appeared to result in increased calf survival in 1987 compared to the west side of Quesnel Lake where wolves were not reduced. However, wolves moved back into the area in September and killed two radio-collared, adult caribou in October. A decline in calf survival corresponded to the return of wolves to the area and by March, calf survival in the wolf removal area was only modestly greater that in the non-removal area (Table 3).

Seven wolves were removed from the study area by shooting and trapping in the winter of 1988 but other wolves were present the following summer and killed two radio-collared adults. Calf survival may have been marginally higher in the summer as a result of the wolf control but by March, the population contained few calves.

Overall, calf survival was greater in October ($G=12$, 1 df, $p < .05$) and March ($G=8$, 1 df, $p < .05$) when wolves were naturally absent or reduced by wolf control (Table 2,3). When wolves were present and uncontrolled, only 2.5% (1/40) of the radio-collared, adult, female caribou had surviving calves in October and there were about 7 calves/100 adults in March. When wolves were absent, or reduced by wolf control, 39% (9/23) of radio-collared, adult females had surviving calves in October and there were about 15 calves/100 adults in March.

When the effect of wolf control alone (excluding the year when wolves were naturally absent) was evaluated, calf survival to October was greater in wolf control areas than in areas where wolves were present and uncontrolled ($G=4$, 1 df, $p < .05$) but calf recruitment in March was not increased ($G=2$, 1 df, $p > .05$), possibly because wolves kept recolonizing the removal areas by late summer.

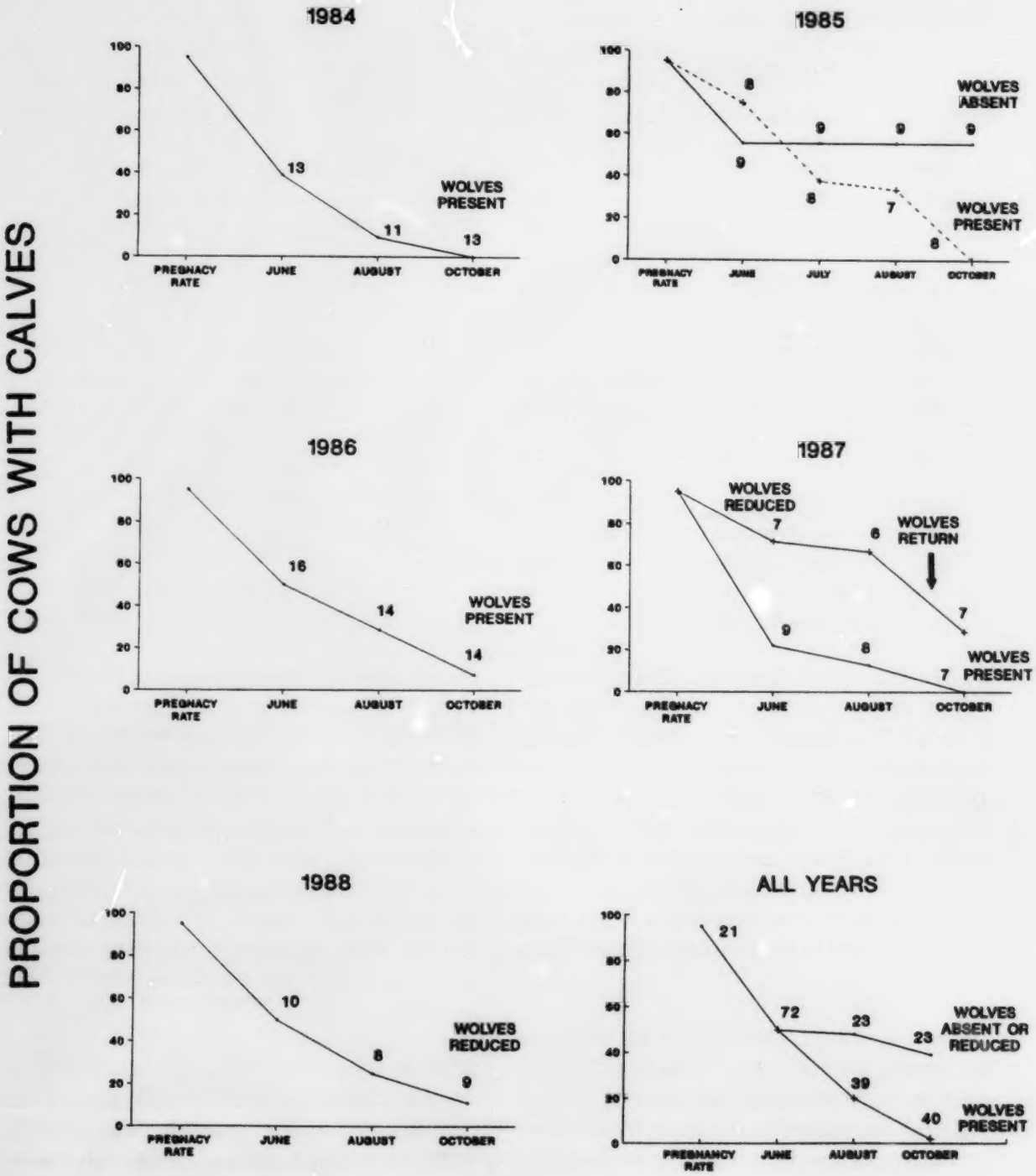

Figure 16. Proportion of radio-collared, adult, female caribou with surviving calves. Number of adult females is given.

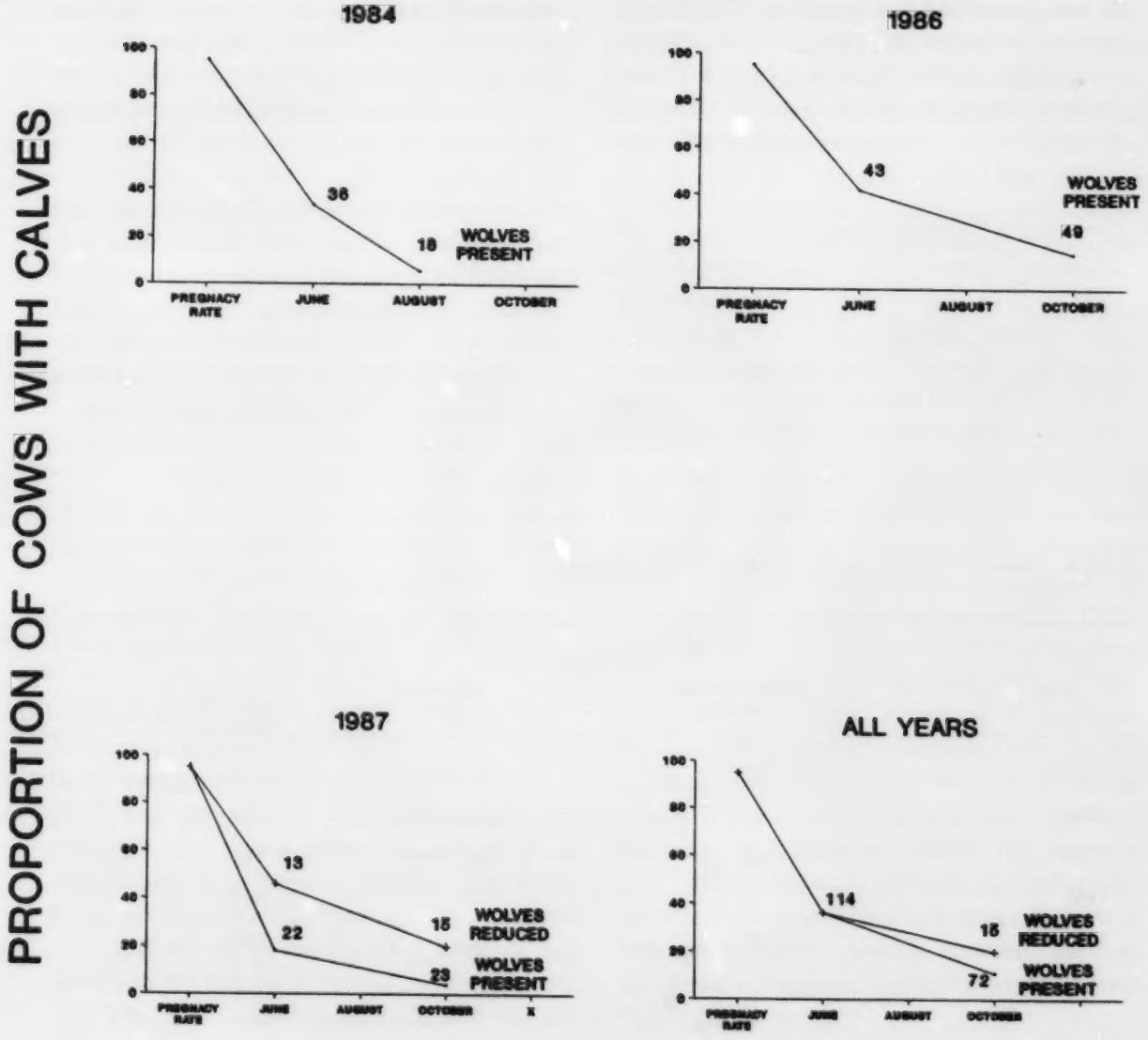

Figure 17. Proportion of all adult, female caribou seen with surviving calves. Number of adult females is given.

Population Status: -- Calf survival to October, combined for all years and areas, was 0.16 calves/radio-collared, adult female (10/63). Assuming a 50:50 sex ratio of calves, about eight female calves/100 adult females survived to October. The number surviving to the age of first breeding would have been even lower. That level of calf recruitment was inadequate to balance the 29% annual mortality rate for adult females and would result in a population decline of about 20-25% annually. Presumably the decline would have been even greater if wolves had not been absent from part of the study area in 1985 and reduced by wolf control in 1987 and 1988.

Population Size and Trend: -- The total number of caribou counted in March declined from 183 in 1986 to 78 in 1989 (Table 4). The proportion of radio-collared animals known to be in the census area that were seen during the census averaged 83% + 12 (SD) and ranged from 75-100% between years. Dividing the total number counted by 0.83 provides a population estimate corrected for animals that were in the study area but not seen during the census. The corrected estimates indicate the caribou population in the study area declined from about 220 in 1986 to 94 in 1989. That decrease represents an annual decline of 26% (r= -0.28, finite rate of increase= 0.754). Therefore, the census data support the conclusion based on survival and recruitment data that the population was declining by about 25% each year during the study. If that rate were to continue, the population would be extirpated during the 1990's.

The caribou density in the 2300 km^2 study area declined from about 0.1 to 0.04 caribou/km^2 between 1986 and 1989. Because about 50% of the study area consisted of preferred winter habitat types (Fig. 10), the density on winter habitats was about double the above values, i.e., a decline from 0.2 to 0.08 caribou/km^2 of winter range.

Table 4. Results of March caribou counts at Quesnel Lake.

Year	Total Number Counted	% Collars Seen	Corrected[a] Population Estimate
1985[b]	118	75 (9/12)	(142)
1986	183	100 (14/14)	220
1987	155	78 (11/14)	186
1988	89	78 (7/9)	107
1991	88	83 (41/49)	106

[a]Total counted/0.83
[b]Incomplete count of study area.

MOVEMENTS AND HABITAT USE OF WOLVES AND MOOSE

Wolf Movements: -- Three of the radio-collared wolves belonged to the same pack. The fourth radio-collared wolf appeared to be a lone wolf that was present in the study area from July 1984 until March 1985. In the summer of 1984, the radio-collared wolves belonging to the pack had an area of concentration indicating a den site south of Spanish Lake. The wolves ranged over the entire area between the Cariboo River and the North Arm of Quesnel Lake. There were sightings and reports of other wolves on the east side of the North Arm that summer. One of the radio-collared wolves died in November 1984, apparently from starvation, after being stranded at high elevation by deep soft snow.

In March of 1985, the pack, including the two surviving radio-collared wolves, crossed on the ice to the east side of the North Arm and remained in that area for the next two years. In the summer of 1985 the den site appeared to be in the Wasko Lake area, based on a concentration of wolf locations. However the wolves ranged over the entire area between the North Arm and the Niagara River, south of Penfold Creek.

In the summer of 1986, the den site of the radio-collared pack appeared to be in the upper Niagara River valley near Christian Lake. In March of 1987, four adult female wolves believed to be members of the pack were shot as part of an experimental wolf control program. One of the radio-collared males, and at least one associated wolf, left the study area soon afterwards and moved to the Rausch River valley 50 km to the east. The other radio-collared male wolf was not found in the study area after the wolf control was conducted but it is not known where it went.

Habitat Use of Wolves and Moose: -- During winter months, the radio-collared moose on the west side of Quesnel Lake were located almost exclusively in low elevation, riparian shrublands and adjacent forests along the Cariboo River (Figs. 18,19,20,21). Although there were no radio-collared moose on the east side of Quesnel Lake, it was apparent from aerial surveys that moose used similar low elevation, riparian shrublands and forests in the Niagara River, Mitchell River and Wasko Creek areas. Radio-collared wolves were located in areas and habitats similar to those used by moose in winter (Figs. 18,19,20,21). Almost no overlap occurred between areas, elevations or habitats used by caribou and those used by wolves and moose in winter, except for those caribou that used low elevation habitats in early winter (Figs. 18,19,20,21). Analyses of wolf scats indicated that wolves were sustained primarily by moose throughout the winter with almost no feeding on caribou (Fig. 22).

In summer, most radio-collared moose migrated to summer ranges at higher elevations and used subalpine forest and forest/meadow complexes (Figs. 19,20,21,23). There was substantial overlap in areas, elevations and habitats used by radio-collared moose and caribou throughout the summer months. Radio-collared wolves were commonly found at higher elevations in subalpine habitats during summer in areas and habitats used by moose and caribou. However, concentrations of wolf locations indicative of denning sites were located at lower elevations. Moose were the major prey item of wolves in summer but caribou and deer were also eaten. Thus in summer, because of substantial habitat overlap between caribou, moose and wolves, wolf predation on caribou was higher than in winter.

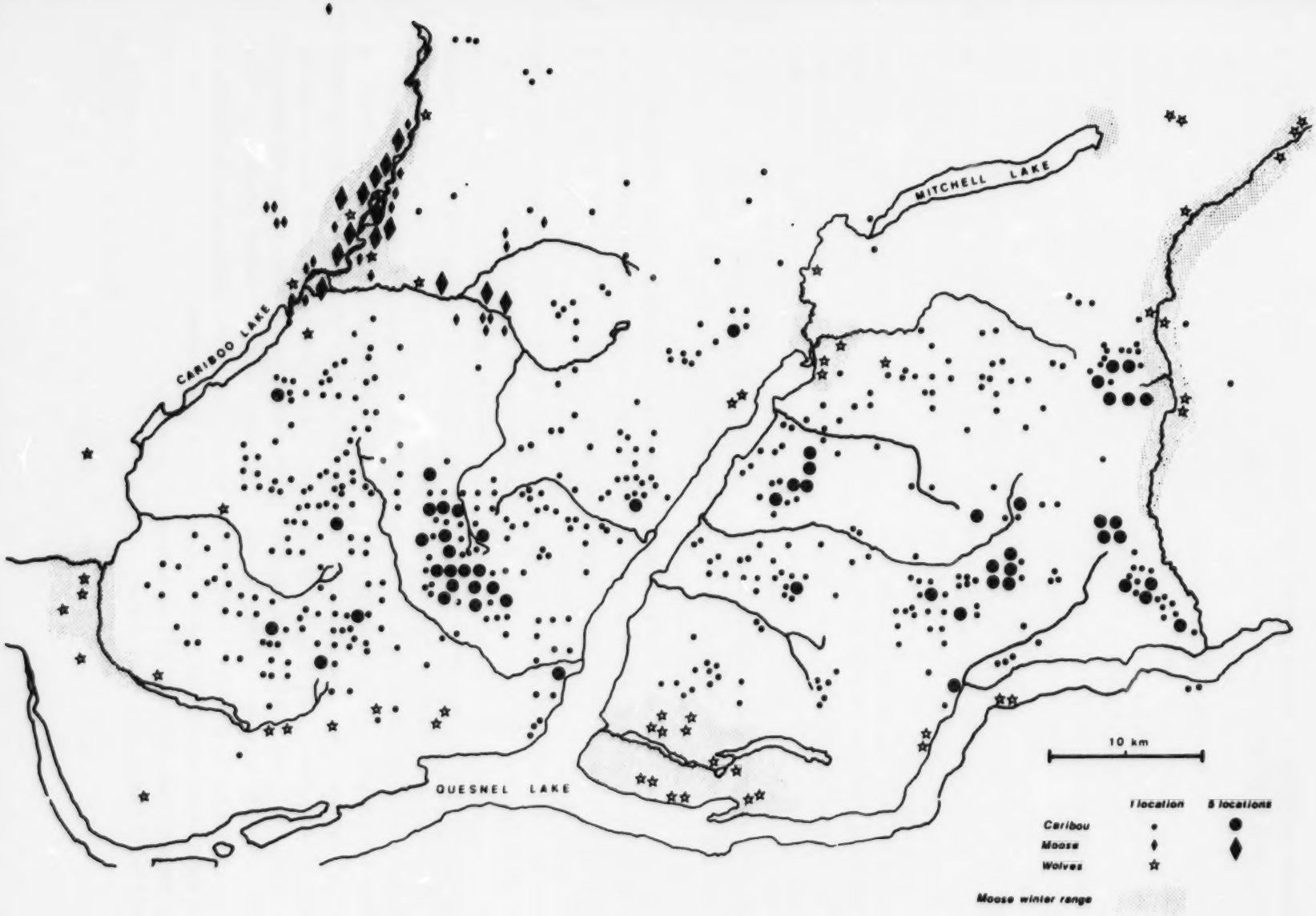

Figure 18. Locations of radio-collared moose, wolves and caribou in winter (Nov.-Apr.).

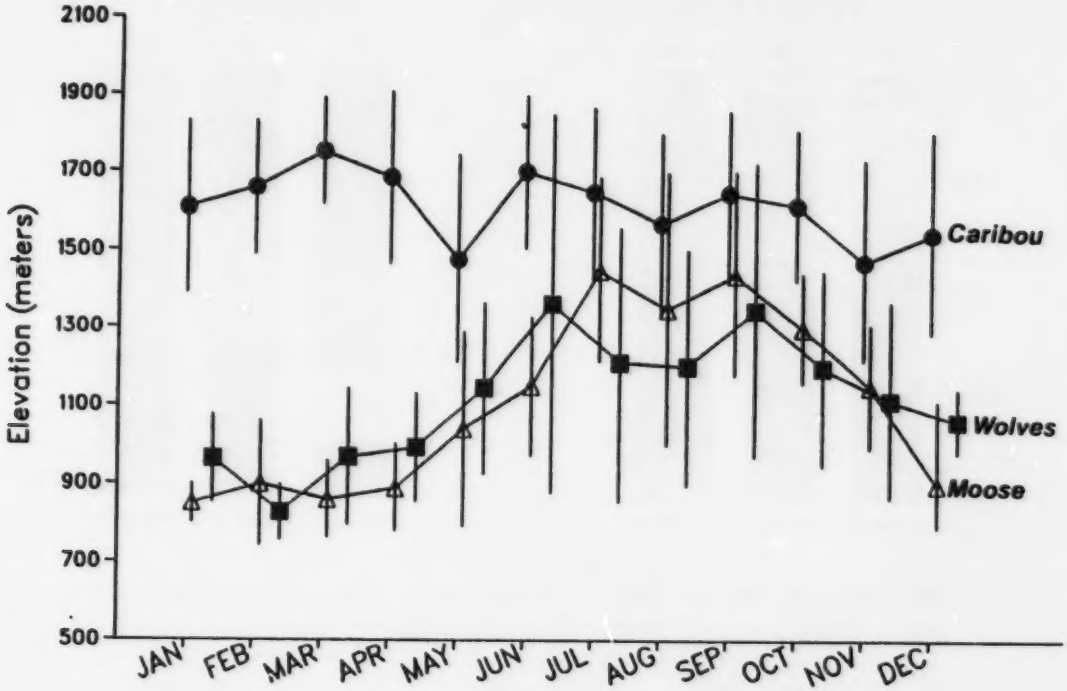

Figure 19. Elevations (X + SD) of caribou, wolves and moose throughout the year.

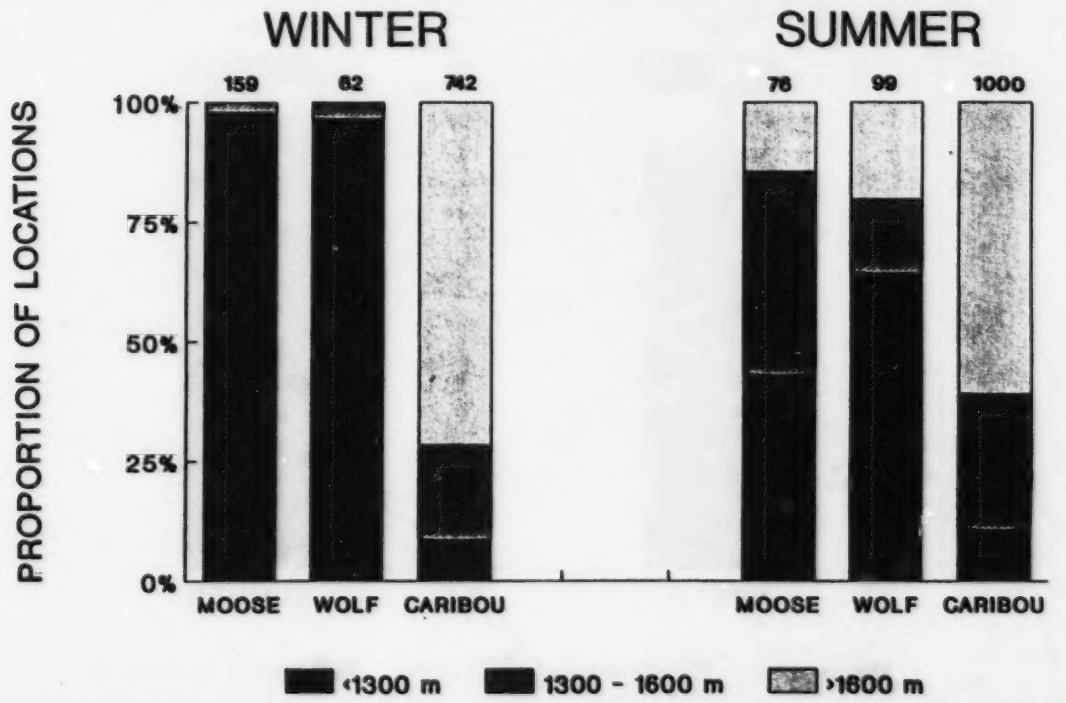

Figure 20. Proportions of moose, wolf and caribou locations at different elevations in winter and summer. Sample size given above each bar.

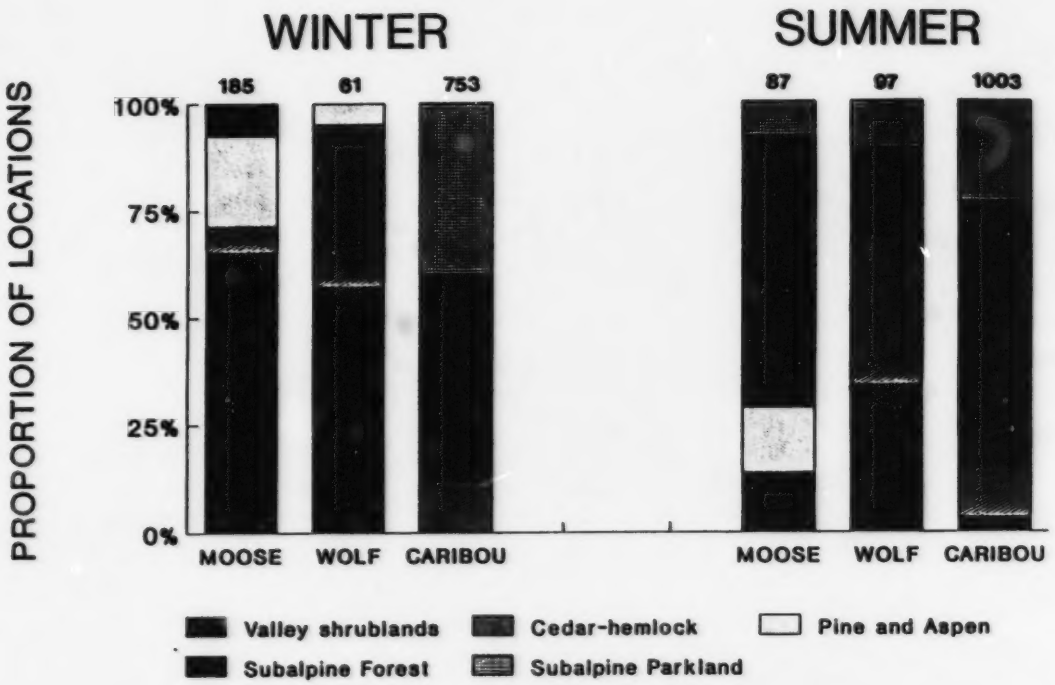

Figure 21. Proportions of moose, wolf and caribou locations in different habitat types in winter and summer. Sample size given above each bar.

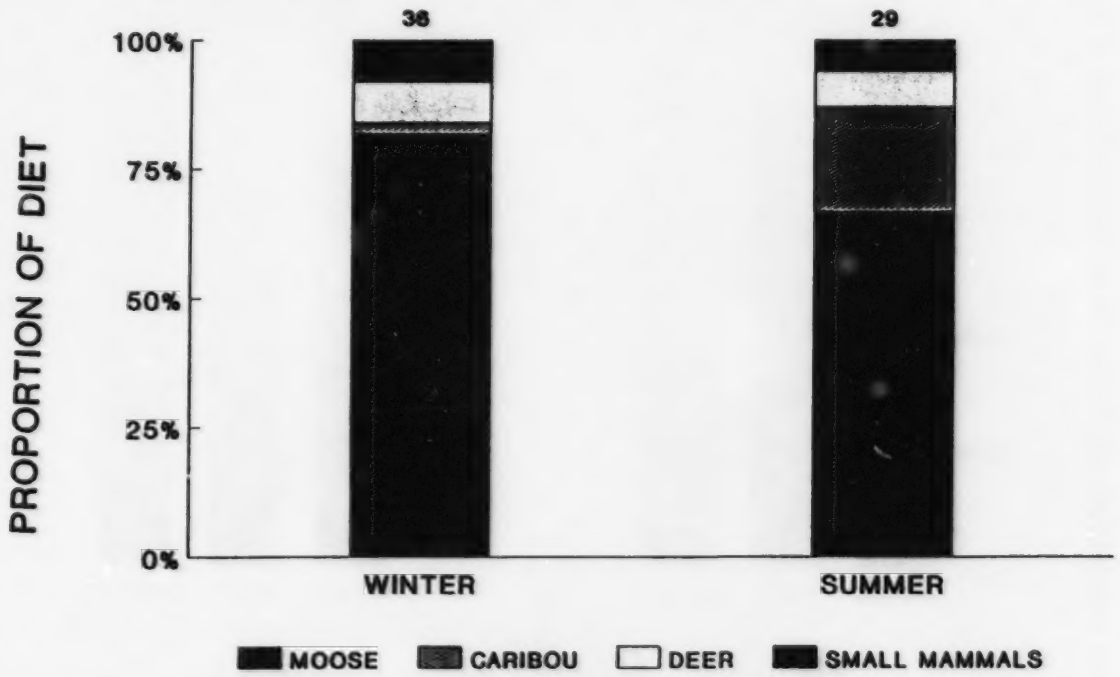

Figure 22. Food habits of wolves in winter and summer based on scat analyses corrected for body size of prey. Sample size given above each bar.

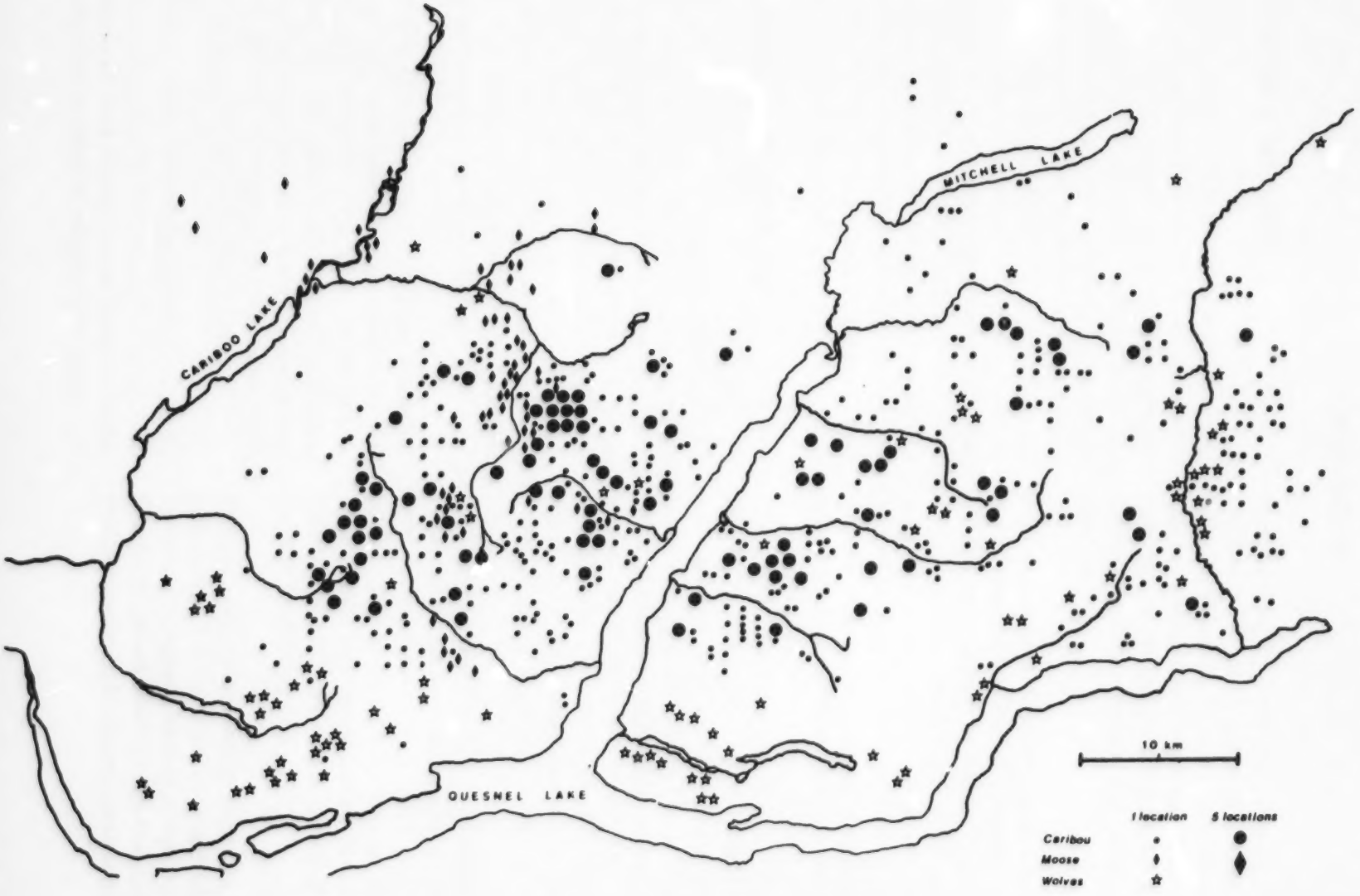

Figure 23. Locations of radio-collared moose, wolves and caribou in summer (May-Oct.).

DISCUSSION

SEASONAL MOVEMENTS

Caribou moved widely during the year over annual home ranges averaging about 250 km^2. Simpson and Woods (1987) reported average annual home ranges of 301 km^2 for caribou near Revelstoke. The caribou often used areas that they had not used in previous years so the longer a caribou was monitored, the greater total area it used. The caribou did not exhibit any distinct migrations from summer ranges to winter ranges but rather used similar areas in both winter and summer. In contrast, most caribou in adjacent Wells Gray Park area migrate up to 60 km between winter ranges in Highland areas and summer ranges in rugged mountainous areas (Seip 1990).

SEASONAL HABITAT USE

Early Winter: -- In November and December, when deep, soft snow began to accumulate at high elevations, some caribou moved to low elevations. About 20% of locations during this period were in low elevation cedar-hemlock forests and about 20% of locations were in mid-elevation spruce/subalpine fir forests. However the majority of caribou locations were in upper elevation subalpine fir and subalpine parkland forest types.

During early winter, caribou selected mature balsam and balsam-spruce forest cover types and avoided immature forest types. About 80% of early winter locations were in forested habitats and only 20% were in open or sparsely forested habitats, probably due to greater accumulations of soft snow in open areas compared to forests.

Caribou using subalpine forests in early winter fed primarily on lichens whereas caribou using cedar/hemlock forests fed on a mixture of lichens, shrubs, forbs and graminoids. Similar food habits have been reported by Scott and Servheen (1985), Antifeau (1987) and Simpson et al. (1987). Despite the difference in diet composition, fecal nitrogen concentrations indicated there was no difference in diet quality between caribou in cedar/hemlock forests compared to caribou in the subalpine.

Early winter use of cedar/hemlock forests by caribou in southeastern British Columbia is quite variable and appears to be related to topography. The majority of caribou which winter in rugged mountains in the Selkirks, Revelstoke area and parts of Wells Gray Park use cedar/hemlock or mid-elevation spruce/subalpine fir stands in early winter (Simpson and Woods 1987; Rominger and Oldemeyer 1989; Sevheen and Lyon 1989; Seip 1990). In contrast, caribou that winter in Highland areas of Wells Gray Park make only limited use of cedar/hemlock stands in early winter (Seip 1990), similar to the Quesnel Lake caribou. Lower snowfall and gentler terrain in Highland areas apparently permits caribou to remain in subalpine forests whereas caribou in more rugged mountains with greater snow accumultations move to lower elevations to avoid deep, soft snow.

At Quesnel Lake, there was considerable individual variation in use of cedar/hemlock stands in early winter. Some caribou never used cedar/hemlock forests during four years of tracking, other caribou used cedar/hemlock forests some years but not others, and some caribou used cedar/hemlock stands every year.

Because caribou feed primarily on lichens during early winter, it is necessary to protect adequate amounts of old-growth forest to provide sufficient forage. Old-growth stands provide abundant arboreal lichens because lichens require slow-growing

or decadent substrate on which to grow. Avoidance of immature stands by caribou suggested that young stands do not provide suitable habitat.

The most important stands to protect for early winter habitat in the Quesnel Lake area are upper elevation subalpine fir and subalpine parkland types represented by mature balsam-spruce, balsam and alpine forest cover types. Those stand types contained about 50% of early winter locations. In addition, some mid-elevation spruce/subalpine fir stands and some low elevation cedar/hemlock stands merit protection as caribou habitat. One possibility would be to link areas of important subalpine forest habitat with corridors of valley-bottom forest that would serve as both early winter range and movement corridors.

Important areas of low elevation cedar/hemlock include the mouth of Grain Creek, Penfold Creek, Watt Creek, Lynx Creek and the Roaring River. Some form of selection logging that retains a perpetual supply of lichen bearing trees, such as the logging prescription for mule deer *(Odocoileus hemionus)* winter ranges in the Cariboo Region (Armleder *et al.* 1986), may provide a suitable alternative to protecting mid-elevation spruce stands in some areas. However, for any modified harvesting system to be an option, it must be feasible to implement the prescription over extensive areas.

Late Winter: -- As winter progressed, caribou gradually moved to higher elevations and used more open habitat types. By March-April, over half of the locations were in subalpine parkland or meadow habitats with the remainder in upper elevation subalpine fir forests. The animals selected alpine and mature balsam-spruce forest cover types and avoided mature spruce, cedar, hemlock and immature forest cover types. Caribou appeared to avoid steep slopes and selected flatter topography such as subalpine bowls, plateaus and ridgetops. The diet during the winter period consisted almost entirely of lichens and conifer foliage. High elevation, sparsely forested stands have the greatest amount of lichen/tree (Antifeau 1987) because the combination of abundant light and very slow tree growth provides excellent growing conditions for lichens. Therefore, high elevation, open stands are preferred habitat in late winter when snow conditions provide adequate support for the caribou to easily move from tree to tree. A similar movement to higher elevation, open habitat types has been reported for all other studies of caribou in southeastern British Columbia (Antifeau 1987; Simpson and Woods 1987; Servheen and Lyon 1989; Seip 1990).

Because caribou depend on arboreal lichens throughout the winter, adequate amounts of old-growth, lichen-producing forest must be protected to provide caribou winter habitat, especially in areas of gentle topography. Protecting mature alpine, balsam and balsam-spruce forest cover types above 1600 m elevation would include over 80% of caribou late winter locations.

Spring: -- In May, a substantial number of caribou used lower elevation cedar/hemlock forests and slides but most continued to use mid and upper elevation forests. Caribou at low elevations were able to feed on new vegetative growth including forbs, shrubs and graminoids. Caribou that remained at higher elevations continued to feed on lichens and conifer foliage although they also obtained mosses and some shrubs indicating that they were able to locate some snow-free areas. Fecal nitrogen concentrations indicated that caribou feeding on new vegetation at low elevations obtained a higher quality diet than caribou at higher elevations. It appears that most caribou sacrificed diet quality by remaining at higher elevations in spring, probably because they are less

vulnerable to predators at higher elevations. Caribou that used low elevation habitats in spring and summer were more vulnerable to predation by bears and wolves.

Summer: -- Throughout the summer, caribou were located primarily at high elevations in subalpine forest, parkland and meadow habitats. Caribou selected mature balsam and balsam-spruce forest cover types and avoided immature forest types. The animals fed on a variety of graminoids, forbs and shrubs but lichens continued to constitute an important food source. Fecal nitrogen concentrations were indicative of high diet quality throughout the summer.

Female caribou were either solitary or in small groups during the calving period with no evidence of large calving aggregations or distinct calving areas.

POPULATION PARAMETERS

Adult Mortality Rate: -- The adult caribou had a very high mortality rate averaging 29% per year. About 55% of mortality for which the cause could be identified was due to wolf predation and 15% was due to bear predation. Accidents and malnutrition were responsible for the remaining mortality. The two cases of death due to malnutrition occurred in summer when abundant, high quality food was available, suggesting that those individuals may have been diseased or old animals unable to feed. No caribou died of malnutrition during winter months indicating that winter food availability was not a major limiting factor for adult survival at these population densities.

Caribou were particularly vulnerable to bear predation in spring and early summer when some caribou fed on low elevation slides and riparian areas frequented by bears. Wolf predation occurred primarily in the summer months when wolves and caribou used similar areas, elevations and habitats. Some caribou that used low elevation forests in early winter were also killed by wolves. No caribou were killed by wolves during late winter, probably because there was spatial and habitat segregation between caribou and wolves during that period.

Calf Production and Survival: -- The adult, female caribou had a pregnancy rate of 95%. That high pregnancy rate indicates that the caribou were not suffering from intense competition for food because food competition leads to reduced pregnancy rates in caribou and reindeer populations (Thomas 1982; Skogland 1985; Messier *et al.* 1988). Although almost all adult females were pregnant, a large proportion of calves were either born dead or died shortly after the calving period. In late June, after the calving period, only about half of the adult females had surviving calves. The cause of that neonatal mortality is not known but other studies have found that newborn caribou calves are vulnerable to a wide range of mortality factors including predators, accidents, and birthing problems (Page 1985; Adams *et al.* 1988). Cichowski (in prep.) found several caribou calves that had been born dead or died at birth on the Itcha Mountains in west-central British Columbia. The observation that major neonatal calf loss at Quesnel Lake occurred even when wolves were absent, and also is reported in other study areas where wolves are low in numbers or absent (Seip 1990; Scott and Servheen 1985), suggests that wolf predation was not a primary cause of early calf mortality.

After the calving period, calf survival was extremely variable and appeared to depend primarily on the number of wolves in the area. When wolves were absent, almost all calves alive in late June survived the summer months and were present in the winter population. When wolves were present and uncontrolled, almost no calves survived the summer. Wolf control significantly increased calf

survival but wolves soon recolonized the area and calf survival then decreased. The major importance of wolf predation as a mortality factor for caribou calves and increased calf survival resulting from wolf control have been demonstrated by numerous other studies (Gasaway *et al.* 1983; Bergerud and Elliot 1986; Adams *et al.* 1988; Farnell and MacDonald 1988).

Population Status: -- The low calf recruitment during the study period was inadequate to balance the high adult mortality rate and the population parameters indicated an annual decline of about 25% each year. Population censuses in March also indicated that the population declined about 25% each year from 220 caribou in 1986 to 94 caribou in 1989. The decline may have been even more rapid if some wolf control had not been carried out during those years. If that rate of decline continues, the Quesnel Lake caribou population would be extirpated during the 1990's. Caribou herds have recently been extirpated from adjacent areas (Stevenson and Hatler 1985).

Adult mortality rate remained high and calf survival rate remained low even though the population declined by over 50% which indicates that within that range of densities (0.1 - 0.04 caribou/ km^2), the major mortality factor (wolf predation) was not density-dependent.

POPULATION LIMITATION OF WOODLAND CARIBOU IN THE QUESNEL HIGHLANDS

The caribou population in the Quesnel Highlands has undergone a major decline from historic levels in the early 1900's and that decline continued during this study. Caribou have disappeared from many parts of their historic range in central British Columbia (Stevenson and Hatler 1985) and if the current rate of decline continues, they will disappear from the Quesnel Lake area by the mid-1990's.

Edwards (1954) and Bloomfield (1980) attributed the caribou declines to destruction of winter habitat and food resources by fires and logging. However, more recent research indicates that winter food abundance is not a major limiting factor at current population densities because:

- winter malnutrition is not a major mortality factor for adults, wolf predation in summer is the major limiting factor;

- adult females have a high pregnancy rate;

- caribou are declining even in pristine wilderness areas in the absence of habitat destruction;

- trailing data indicate that caribou often walk by potential food without feeding (Simpson *et al.* 1987) and arboreal lichens generally appear to be superabundant on winter ranges;

- the rate of population decline is not density-dependent at the current density levels; and

- estimates of lichen availablity greatly exceed caribou requirements.

For example, the Quesnel Lake study area contained about 80 000 ha of subalpine winter range. Arboreal lichen within reach of a caribou in those forest types ranges from 50 to 200 kg/ha (Stevenson 1979; Van Daele and Johnson 1983) for a total of 4 to 16 million kg of lichen available in the study area. Stevenson (1979) determined that arboreal lichens have an annual sustainable yield of about 13%. Therefore, lichens in the study area would provide a sustainable production of 525 000 to 2 million kg of lichen within reach of caribou. Over the winter, each caribou can consume about 450 kg of lichen based on a daily consumption rate of

2 to 3 kg/day (White *et al.* 1981). Therefore, the study area should be able to support several thousand caribou without depleting the food resource. On the Slate Islands in Ontario, Bergerud (1983) found that in the absence of predators and hunting, caribou were regulated by arboreal lichen availability at a density of 4-8 per km^2, a density 40 to 80 times greater than the Quesnel Lake population.

Therefore, it appears that current caribou population declines in the Quesnel Highlands cannot be attributed to a lack of food resulting from habitat destruction.

Bergerud (1974) and Bergerud and Elliot (1986) proposed that caribou declines were related to increased moose populations in central British Columbia during the 1900's that sustained increased wolf numbers and resulted in increased wolf predation on caribou. The results from the Quesnel Highlands support that hypothesis.

Wolf predation was the major cause of adult mortality and appeared to be responsible for the high rate of calf mortality. Caribou were not vulnerable to wolves in winter because caribou lived in subalpine forests whereas wolves were located in valley bottoms where they preyed primarily on moose. A similar spatial separation between caribou and wolves/moose occurs in Wells Gray Park during the winter months (Seip 1990).

Caribou became vulnerable to wolves in summer. Most moose migrated to summer ranges in the subalpine. Wolves were also regularly found in subalpine areas in summer, resulting in extensive overlap in areas, elevations and habitats used by caribou, wolves and moose. Throughout the year, movements and habitat use of wolves closely reflected the movements and habitat use of moose. Although moose continued to be the major prey of wolves in summer, a large proportion of caribou adults and calves were also killed, resulting in declining caribou numbers.

Wolf predation on caribou remained high throughout the study period even though there was a major decline in the caribou population. The predation rate on caribou was not density-dependent because the wolf population was sustained primarily by moose, regardless of any decrease in caribou numbers. Therefore, wolf predation could lead to extirpation of caribou, because moose are present to sustain the wolf population even if caribou numbers decline.

In Wells Gray Park, most caribou migrated from winter ranges in Highland areas to summer ranges in rugged, mountainous areas (Seip 1990). That migration resulted in most of the caribou being spatially separated from wolves and moose during summer and winter. Consequently there was a low wolf predation rate on the migratory caribou in Wells Gray Park. However, some of the caribou remained in or adjacent to Highland areas in summer, close to areas used by moose and wolves. Those caribou had low calf survival and high adult mortality rates comparable to Quesnel Lake. Caribou numbers in those parts of Wells Gray Park drastically declined in recent years (Seip 1990). It appears that if caribou, wolves and moose occupy similar summer ranges, wolf predation can greatly reduce or eliminate the caribou. Migrations of caribou that result in spatial and habitat separation between caribou and wolves/moose allow the three species to co-exist. The non-migratory behavior of caribou at Quesnel Lake resuits in extensive overlap between caribou, wolves and moose on summer ranges and consequently wolf predation appears to be extirpating the caribou.

Prior to the 1900's, moose were uncommon or absent in central British Columbia. Some people believe that moose were totally absent before the 1900's and colonized the Quesnel Lake area about

1930 (Hatter 1950; Edwards 1956). Spalding (1990) challenged that idea and concluded that moose were present at low numbers in isolated pockets throughout British Columbia in the 1800's but increased in number during the 1900's. In either case, there was a major increase in moose numbers in central British Columbia in the early 1900's. Before moose arrived or increased in numbers, wolf populations in the Quesnel Lake area were probably low due to a lack of available prey in winter. Use of high elevation habitats by caribou and mountain goats *(Oreamnos americanus)* in winter makes them largely invulnerable to wolves. Mule deer are uncommon in the area during winter due to deep snow.

Moose colonized or increased in the Quesnel Lake area about 1925-30 (Edwards 1956). Moose provided an available prey species in the valley bottoms that could sustain wolf populations during winter months. The first reports of major caribou declines commenced soon after the arrival of moose was reported in the area (Report of Provincial Warden, cited in Stevenson and Hatler 1985). Thus both historic data and research results support the hypothesis that increased wolf populations sustained by moose are the primary cause of caribou declines in the Quesnel Lake area. In the absence of wolf control (or moose reduction), the population may be extirpated in the near future.

MANAGEMENT RECOMMENDATIONS

POPULATION MANAGEMENT

1. The Quesnel Lake caribou population was rapidly declining, primarily due to wolf predation, during this study and would soon be extirpated if that rate of decline continued. Wolf control is probably necessary to allow the caribou population to increase and may be necessary to prevent further decline. If on-going monitoring indicates the decline is continuing, wolf control is probably necessary to save the caribou.

Efficient wolf control in the area is difficult because of heavy forest cover and limited access. Also, wolves from outside the area quickly recolonize the area following control programs. A program to reduce the moose population, the major prey species of the wolves, in combination with wolf control would greatly increase the probability of success.

However, the decline of caribou is a natural process related to the increase in moose and wolves in central British Columbia. The public may prefer to let this process continue and allow the caribou to be extirpated, rather than controlling wolves to protect caribou.

2. Although there is no evidence that the recent male-only hunting seasons for caribou have significantly contributed to the population declines, the hunting season for male caribou should be reconsidered. Although the pregnacy rate was high, indicating that there was no lack of bulls during the study period, a hunting season for bull caribou in the area increases the risk to the population. An open season on bulls increases the chance that female caribou will be accidently shot.

HABITAT MANAGEMENT

If wolf predation can be successfully reduced, the habitat in the Quesnel Lake area has the potential to support a large population of caribou, probably in excess of a thousand animals. Because caribou rely on arboreal lichens for winter forage, protection of sufficient areas of old-growth forest is required to maintain caribou populations. Caribou avoided immature stands during all seasons of the year.

How much habitat do they need?

The food requirements of the current low caribou population could be met by protecting only a small portion of the habitat. However, caribou ranged over all suitable habitat in the study area and the opportunity to space out over large amounts of suitable habitat probably enhances their survival by reducing the encounter rate with predators and poachers. If an effective wolf control program is implemented, the caribou population could eventually reach a size that would require all of the suitable habitat types to provide sufficient food resources

Which habitat types should be protected?

In order of priority, the most important habitats to protect are:

1. Mature subalpine fir forests and parkland habitats at upper elevations (>1500 m), especially in areas of gentle topography such as bowls, plateaus and ridgetops. These areas represent the upper variant of the ESSFh subzone and include alpine, balsam and balsam-spruce forest cover types. Those habitat types include 50-60% of early winter locations and about 80% of late winter locations. They also include the majority of

summer locations. Given the generally lower timber values, low productivity and reforestation problems associated with those upper elevation habitats, they could be protected as caribou habitat with minimal impacts on timber production.

2. Some mid-elevation (1200-1500 m) stands of mature spruce/subalpine fir are used in early winter. These areas represent the lower variant of the ESSFh subzone and include spruce and spruce-balsam forest cover types. About 20% of early winter caribou locations occured in these stands. Partial cutting techniques that retain a perpetual supply of lichen-bearing trees, similar to the prescriptions for mule deer winter ranges in the Cariboo (Armleder *et al.* 1986), may provide alternatives to totally protecting these stands but further research is needed to evaluate that approach. Corridors of mid-elevation and valley-bottom forests linking areas of important subalpine habitat could be used to provide both early winter range and movement corridors.

3. Low elevation cedar/hemlock stands, especially in areas along the shores of Quesnel Lake, provided early winter habitat for some caribou. About 20% of early winter locations were in low elevation cedar/hemlock stands. In particular, the mouth of Grain Creek, Penfold Creek, Watt Creek, Lynx Creek and the Roaring River were used in early winter.

ACCESS MANAGEMENT

Poaching was not a major mortality factor for caribou during the study period, probably in part due to the lack of easy access to most of the area. However, in areas of caribou habitat in southeastern British Columbia that have easy access, poaching is a major mortality factor (Johnson 1985; Seip and Stevenson 1987). Given the already precarious status of the Quesnel Lake population, any additional mortality due to poaching is unacceptable. Therefore, road access should be limited in areas of caribou habitat. Although there was no evidence that roads interfered with caribou movements, uncontrolled road access does greatly increase the potential for poaching and disturbance.

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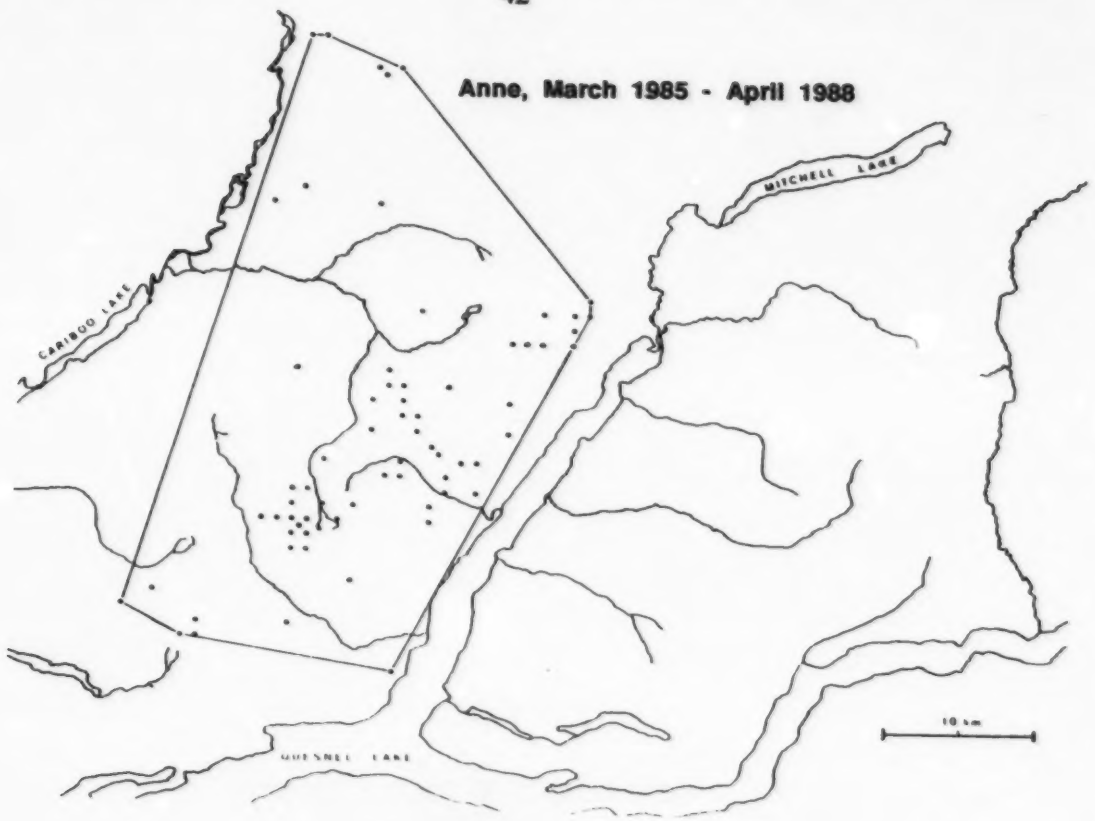
APPENDIX A.

Home ranges of radio-collared caribou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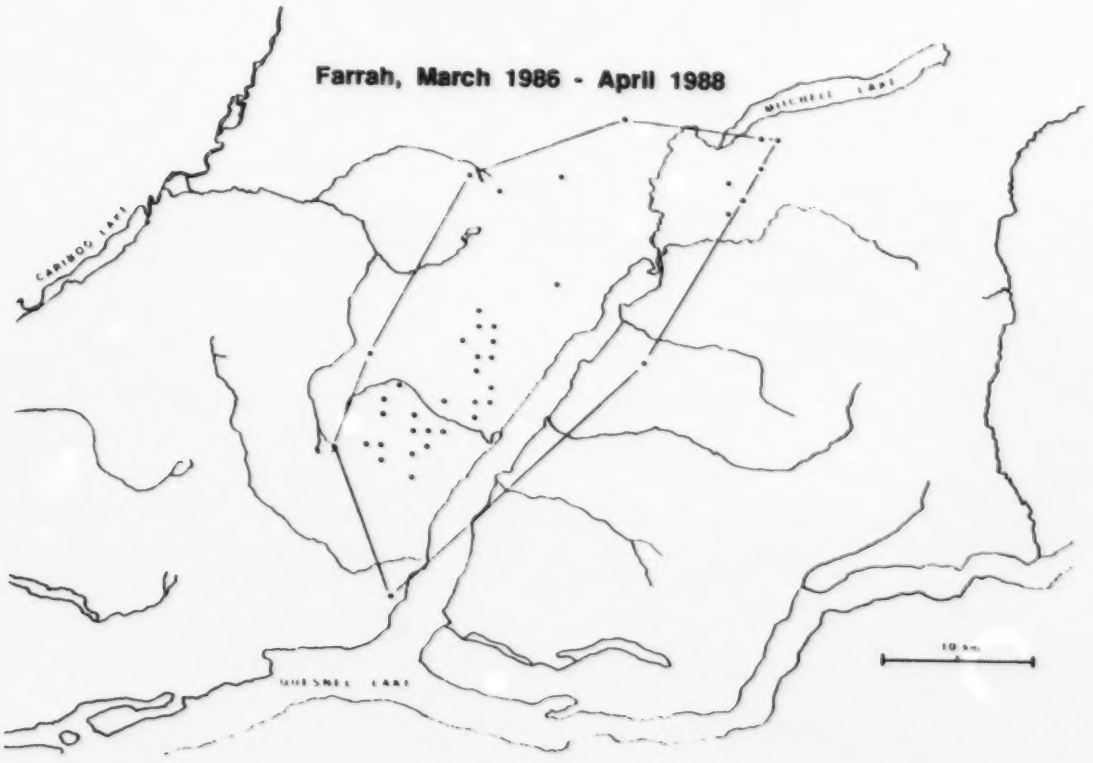
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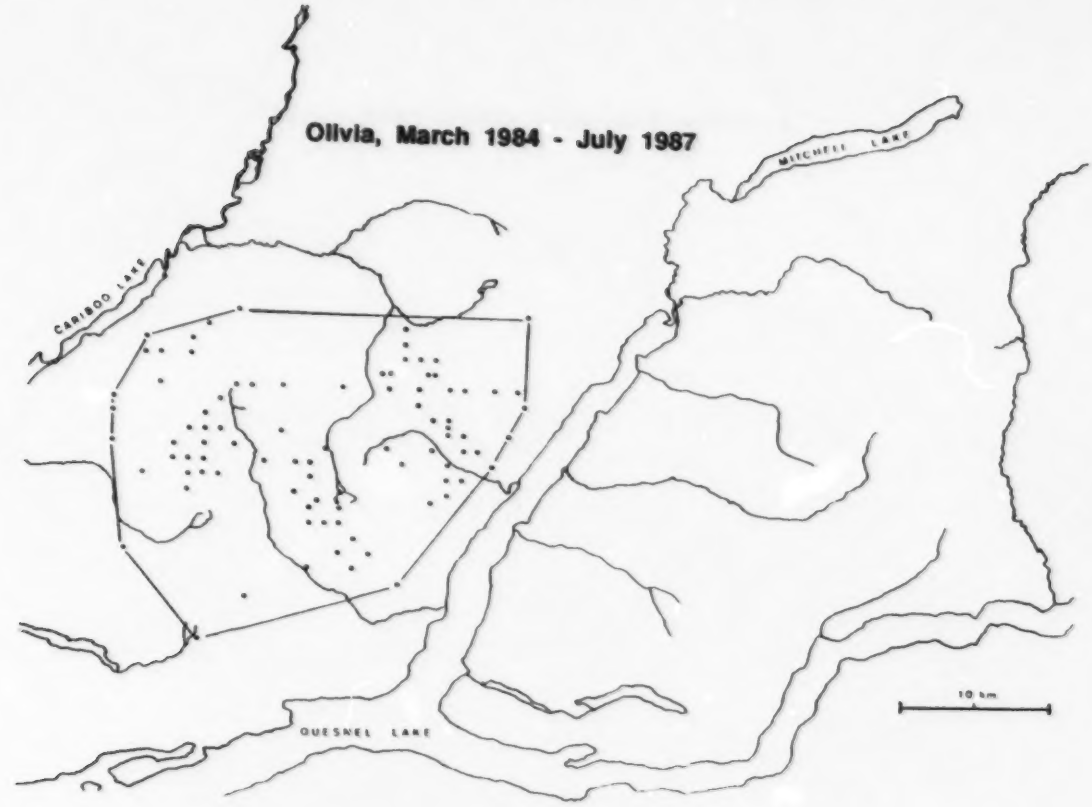
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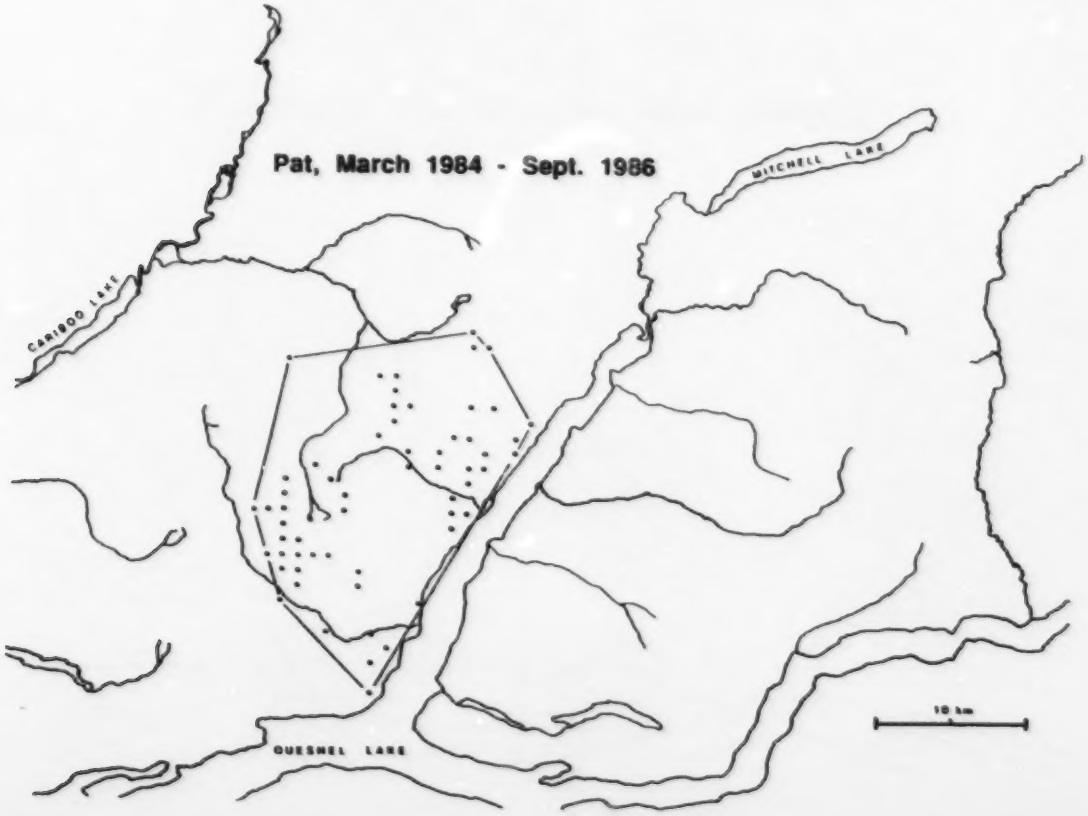
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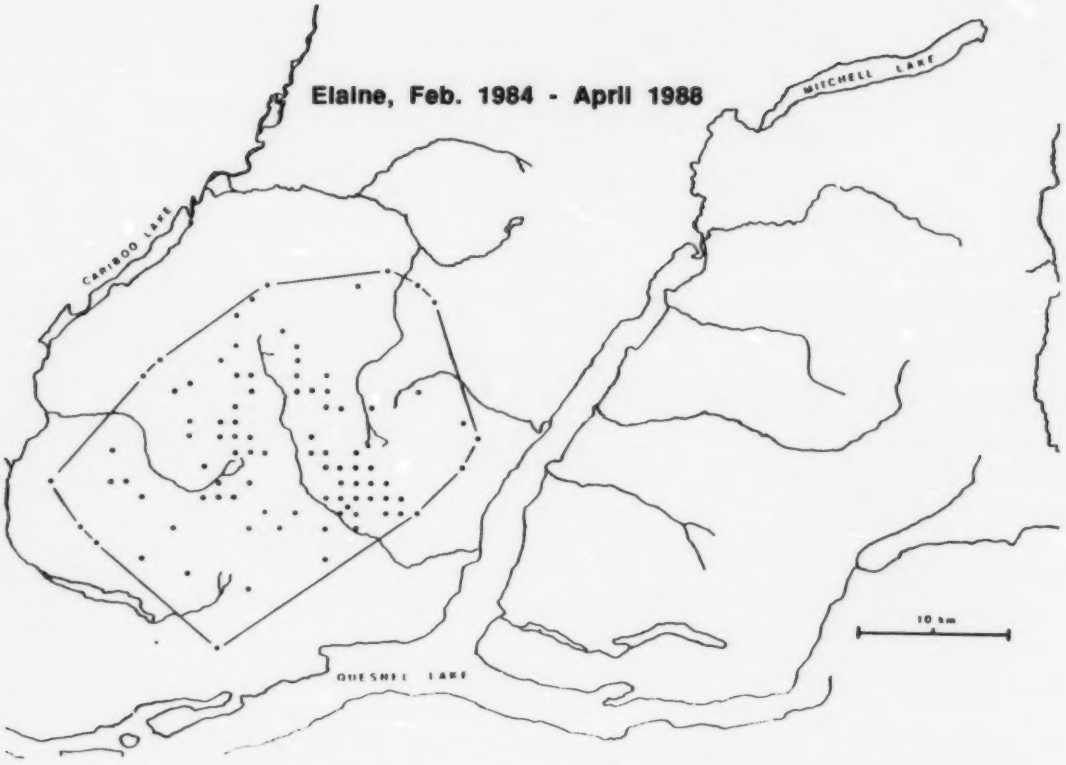
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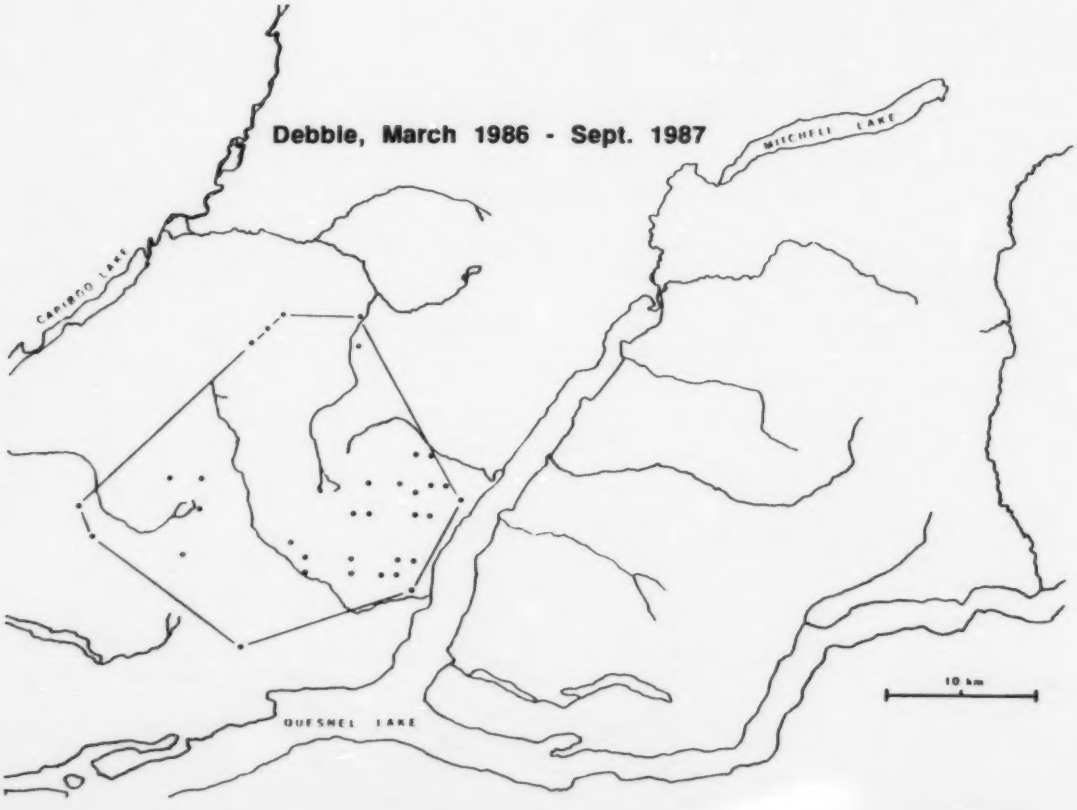
QUESNEL LAKE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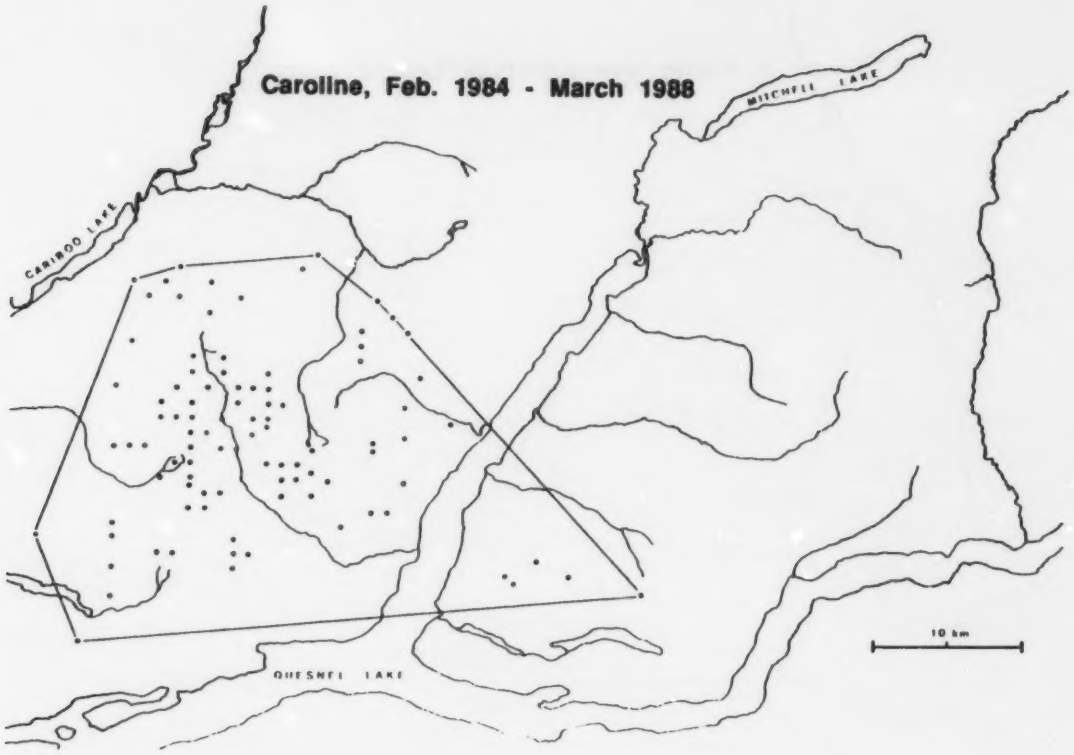
QUESNEL LAKE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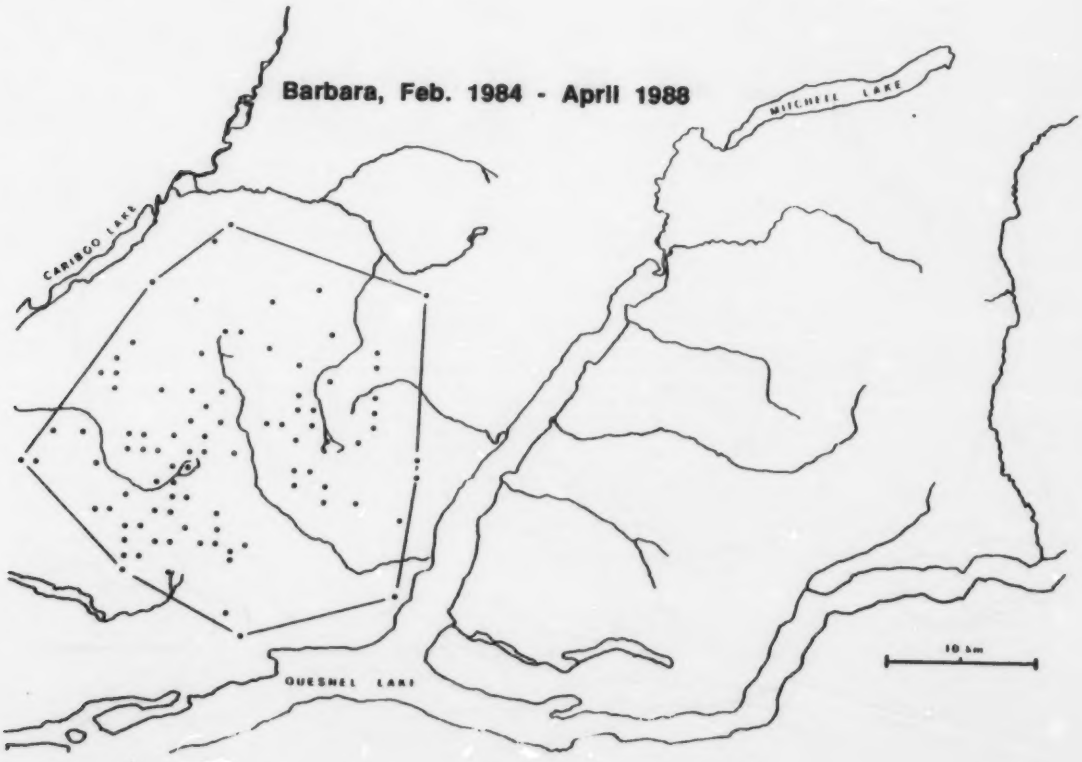
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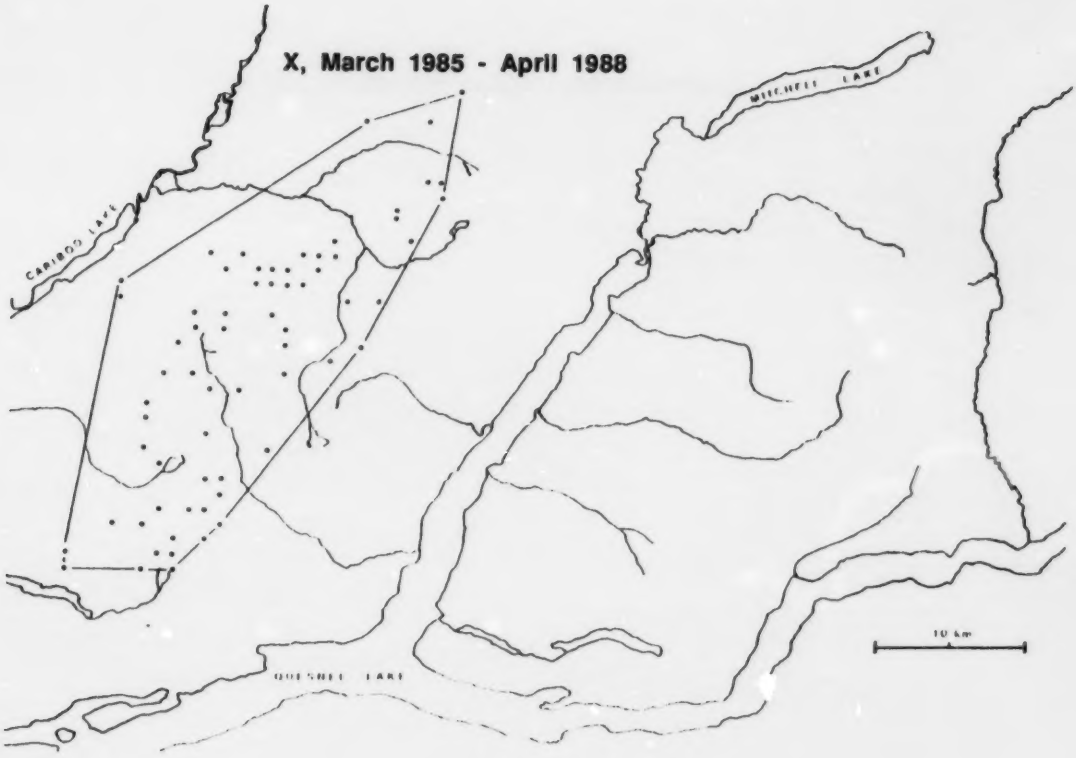
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QUESNEL LAKE
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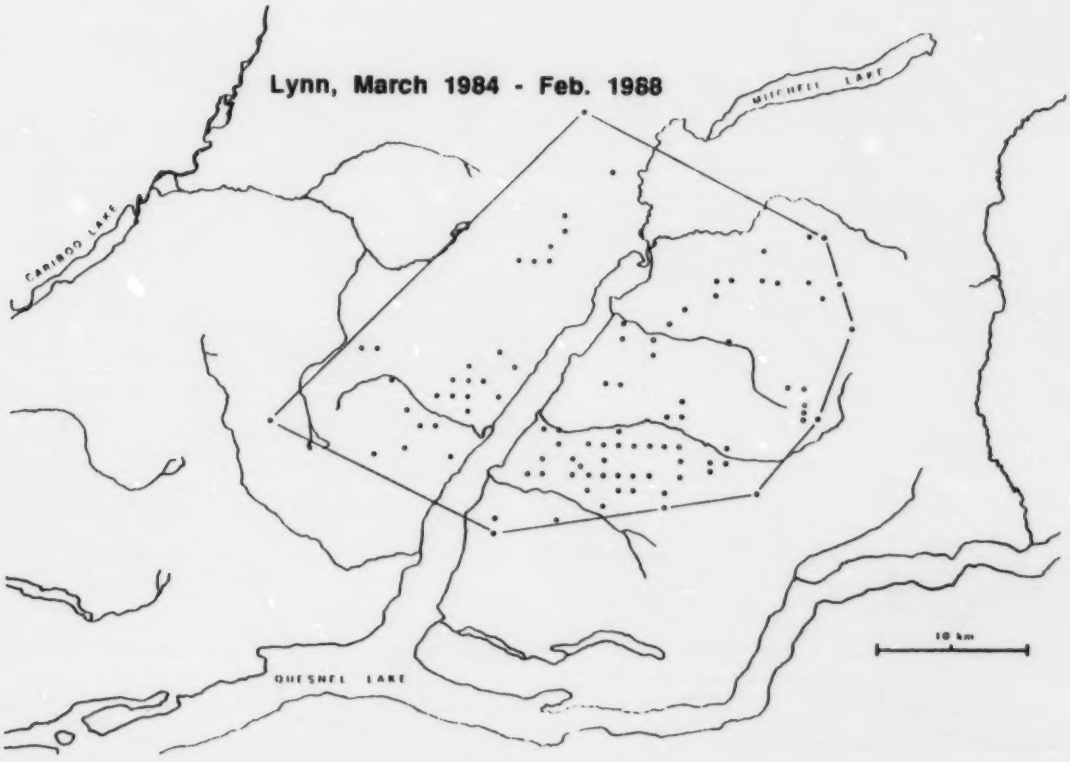
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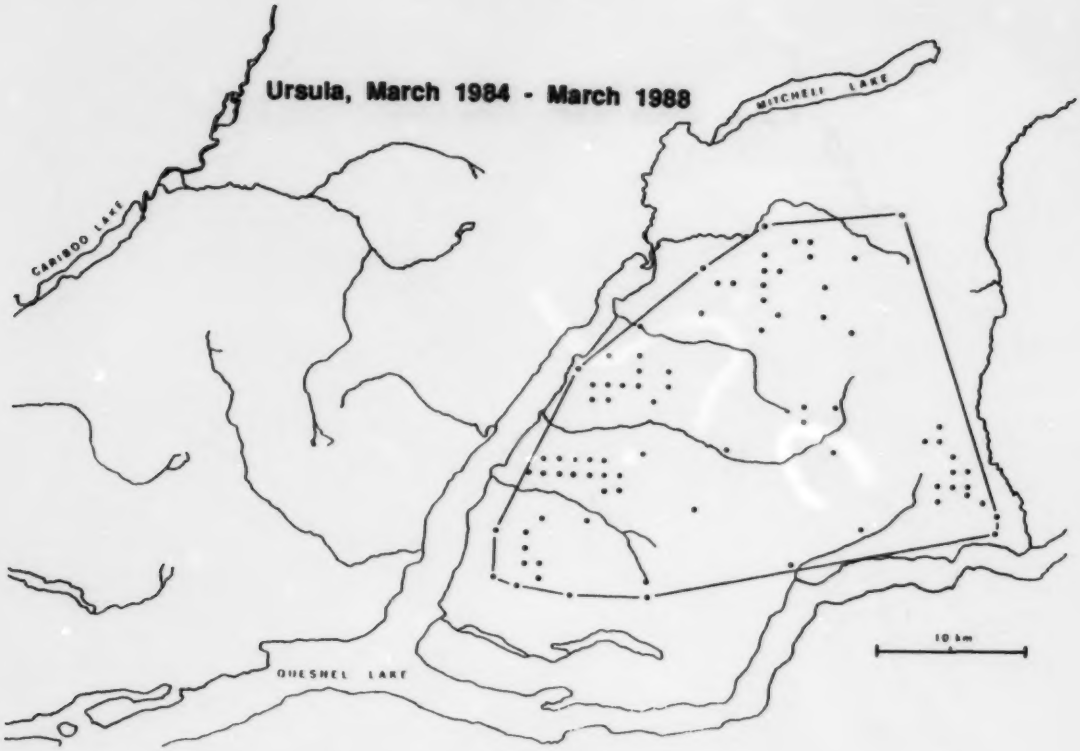
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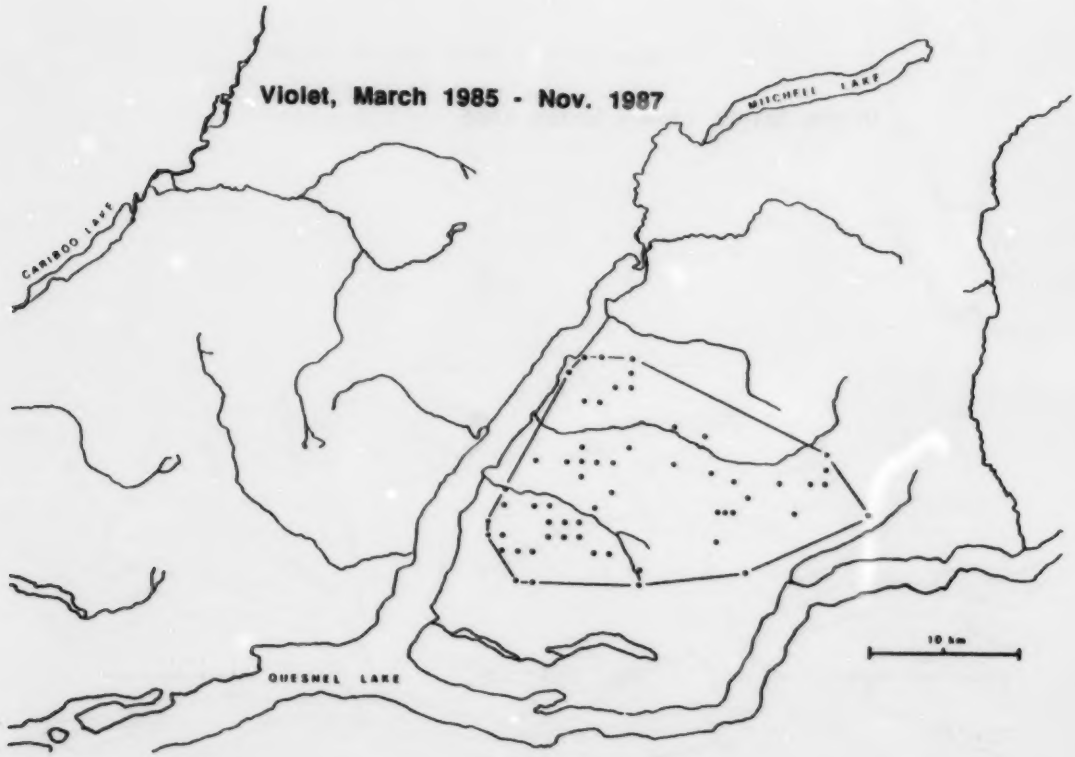
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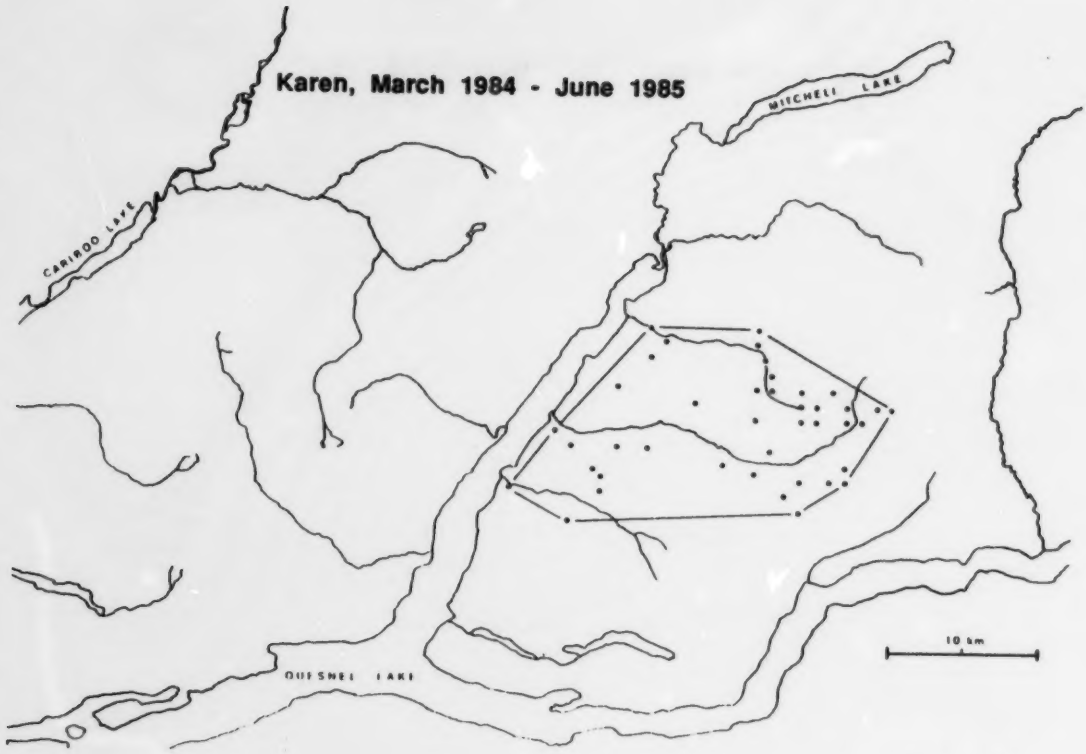
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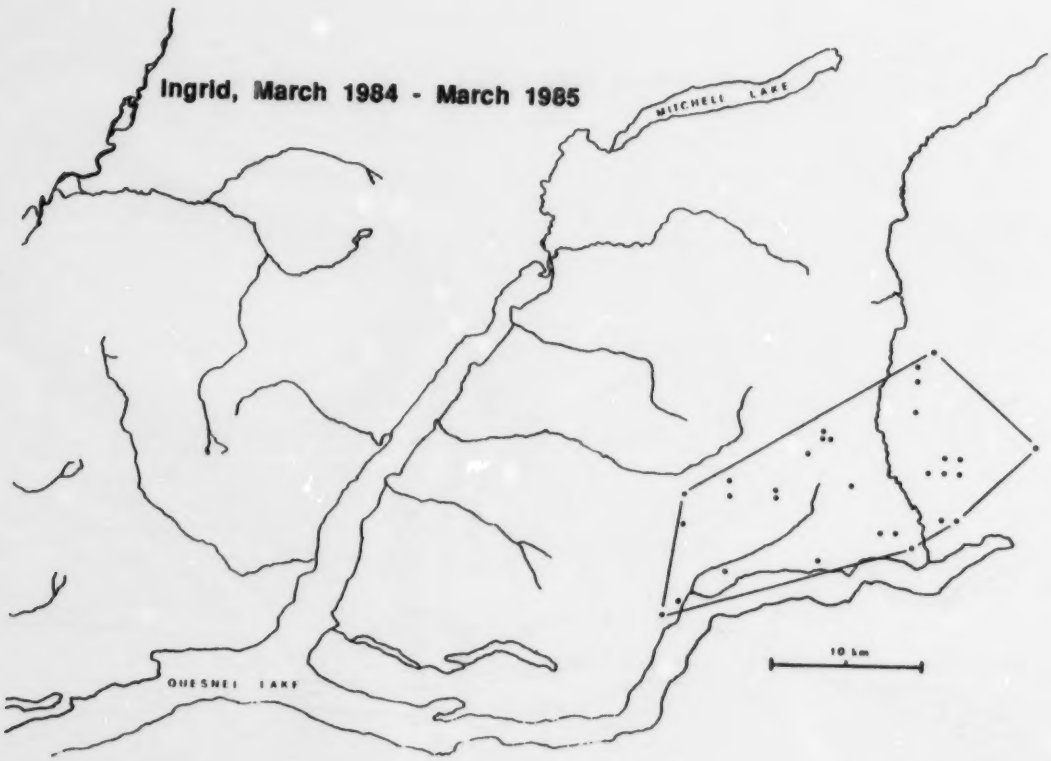
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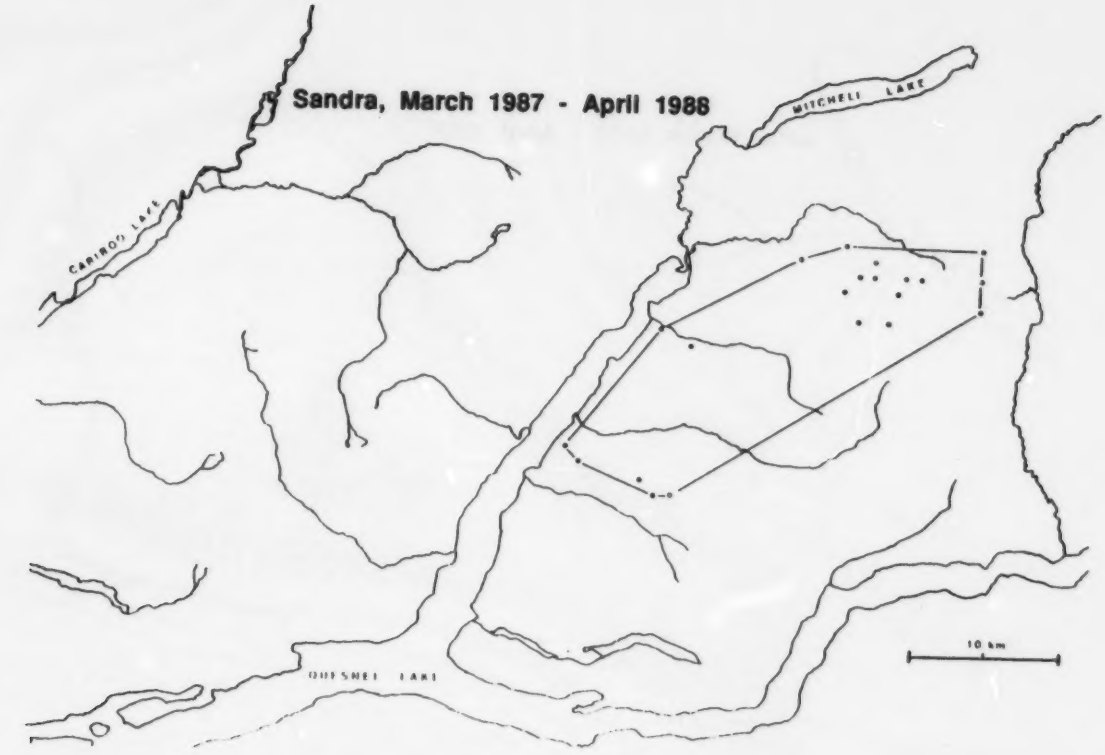
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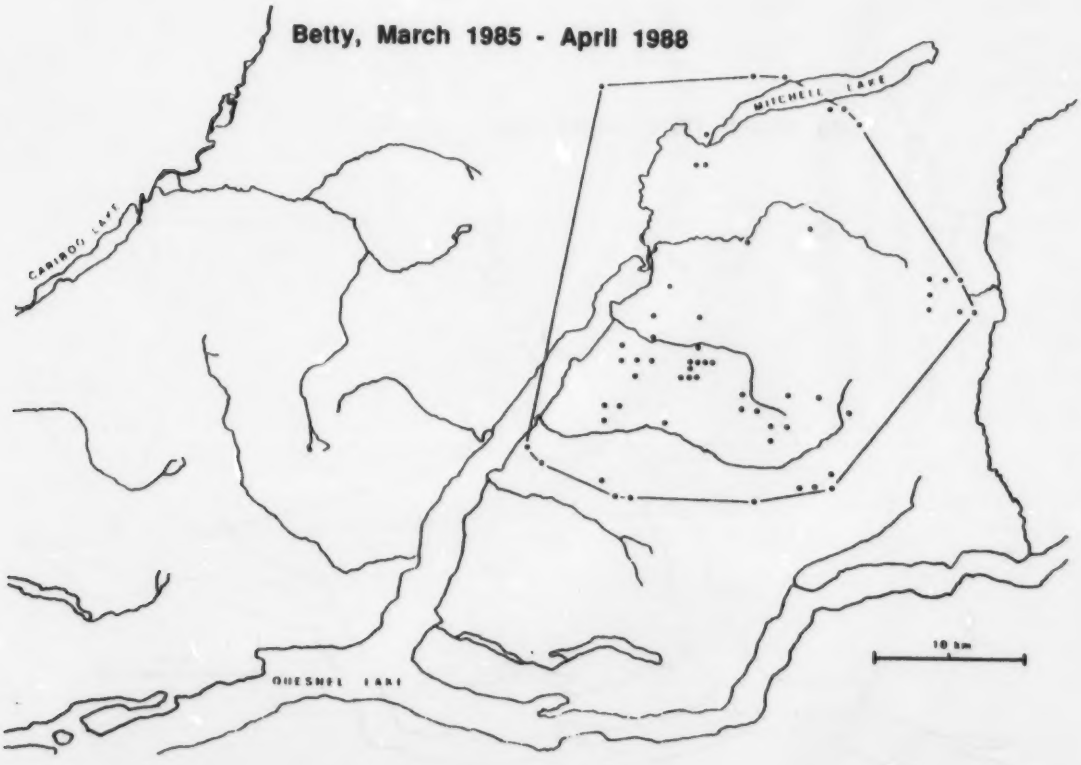
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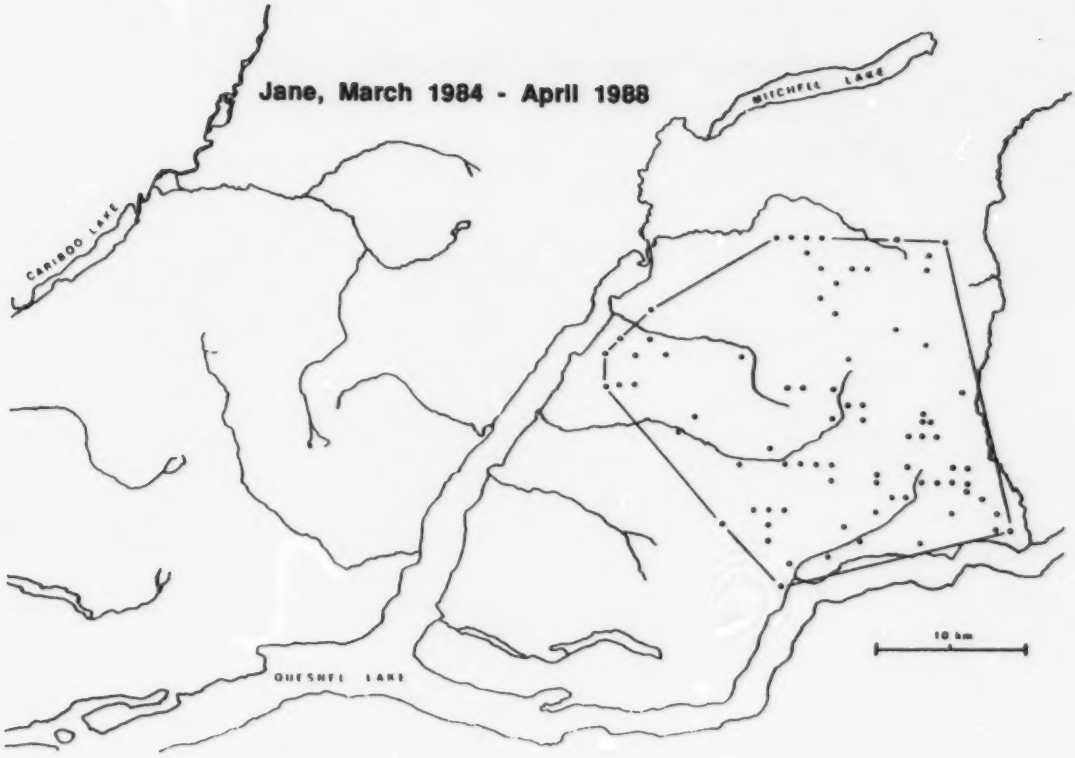
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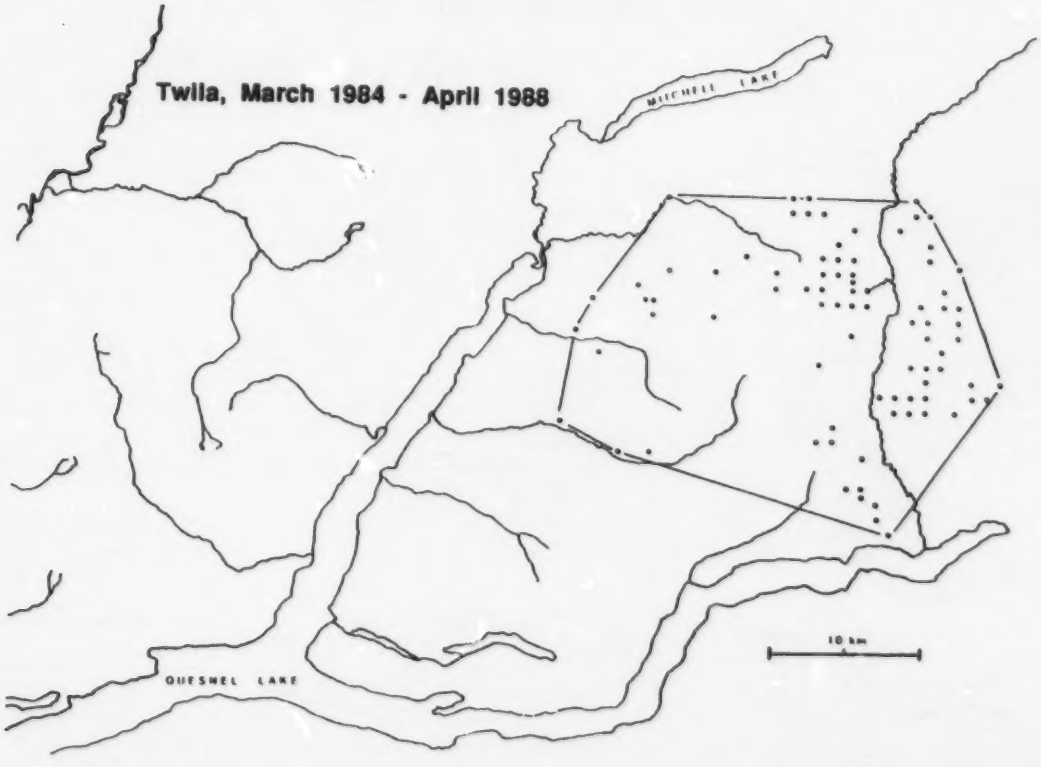
Twila, March 1984 - April 1988
MITCHELL LAKE
QUESNEL LAKE
10 km

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